Chained-Services Based Marine SDI Geoportal

A Reference Architecture using RM-ODP and UML

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by

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I certify that although I may have conferred with others in preparing for this assignment, and drawn upon a range of sources cited in this work, the content of this thesis report is my original work.

Signed …………………….

Disclaimer

This document describes work undertaken as part of a programme of study at the International Institute for Geo-information Science and Earth Observation. All views and opinions expressed therein remain the sole responsibility of the author, and do not necessarily represent those of the institute.

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Abstract

This study has been motivated by the need to develop specifications for National Spatial Data Infrastructures. A geoportal, a single point access to data, services and applications , is a primary pillar of an NSDI. The Geoportal's architecture needs to be based on Open Distributed Processing (ODP) to meet its aims of making available information and processing resources in a heterogeneity of platforms and domains. In addition to heterogeneity, ODP systems exhibit properties like remoteness, concurrency, partial failure, concurrency, autonomy, modularity. The sheer range of complexity has led to efforts at ODP standardisation. The functionalities provided across an ODP have been captured in the concept of common services. ODP standardisation, structures and controls the heterogeneity, by agreeing to a mechanism of grouping properties of different services. To support structuring the content of a distributed system into a set of common services a framework is required for system specification. Reference Model of Open Distributed Processing (RM-ODP) is an ISO/IEC standard which provides this framework. The unique thing about this standard is the introduction of standardized viewpoints. Enterprise viewpoint focusing on objective, scope, and policy; computational viewpoint focusing on functional decomposition of system etc. Each viewpoint is expressed in a separate language comprising of precisely defined concepts, rules and structures which share the the same underlying semantics. RM ODP is claimed to be designed to cater to all known architectural requirements for distributed systems.

The specifications for the interfaces constituting the services are being developed by Open GIS Consortium (OGC) an industry consortium, in collaboration with ISO technical committee 211 dealing with Geospatial standards. The ISO and OGC both have adopted RM-ODP as the reference model for their standards.

Though RM-ODP is available since mid nineties much architecting based on it is not apparently available specially for SDIs. It has been observed that it is partly because RM-ODP specifies no methodology or notation for modelling. This study has aimed to establish a methodology and to demonstrate use of UML to develop a reference architecture, for a marine SDI geoportal , based on the RM-ODP framework. A reference architecture is a platform independent model of the envisaged system. It specifies a business, the required system and the system's place in the business. It serves to delineate the system boundaries, defines options and lays down a structure for all intermediate states of the system as it evolves towards a target architecture.

In addition to producing an architecture of an ISO/OGC services based Geoportal, in RM-ODP, the study serves two other purposes. It demonstrates how UML could be used to capture the RM-ODP based architecture in models. It gives an insight into the claim that RM-ODP's conceptual formalism ensures semantic interoperability between the specifications of the business domain and the specifications of the corresponding system aspects. It was seen in the study how a business model and the system components model comprising a platform independent reference architecture , can be developed on the principles of separation of concerns using three separate architectural viewpoints. It was seen that UML is an effective and precise tool for capturing the specifications suitably annotated with text. In developing the reference architecture both in the author's opinion a useful instrument contributing to the SDI movement was created but the value of RM-ODP in devel-

oping such instrument was also demonstrated. The architecture was also tested for internal consistency based on rules of internal consistency defined in the standard. This was demonstrated by identifying correspondences between different viewpoints. Apart from the consistency of the architecture these correspondences also reflect the logical consistency claimed by the promoters of the standard. Based on the experience of this architecture , supported by literature research during this study , it is recommend that use of RM-ODP in conjunction with UML be promoted as a standard for developing system specifications for SDI applications.

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1. Introduction

1.1. Geoportal , Web Services, and Reference Architecture

It has been reported that greater than 80% of business and government information has some reference to location [1]. A need has been recognised to empower civil society with geo-information by integrating it with the IT infrastructure. The metaphor of Spatial Data Infrastructure has been widely welcomed to meet this need. But it begins as a hazy picture and lingers as a lazy thought. To elicit something tangible from this metaphor, a blueprint of the desired system is necessary. This thesis deals with this critical stage in the process of realizing an SDI - creation of reference architectural specifications of a Geoportal for the purpose of building a framework to spiral towards the target architecture.

The Geoportal considered here is based on the concept of Services. The march of interoperability has been roughly along format conversions to interchange formats , to vendor APIs. But they tend to remain tied to vendor's products . The idea of open common interfaces was conceived to overcome this situation. The APIs technology offers an architectural design called the Service Oriented Architecture (SOA) where functionalities are accessible through interfaces, without any knowledge of the underlying platform necessary for the user. SOA stands for "an application architecture within which all functions are defined as independent services with defined invokeable interfaces , which can be called in defined sequences to form business processes." [2].

A service is a network enabled component which can be reused without knowledge of how the service is implemented. This together with the fact that web protocols are largely neutral wrt vendor, platform, and language enables availability of erstwhile monolithic GIS as unbundled functionalities and data. It also serves to integrate Geoprocessing and Geodata in a distributed environment.

ISO, an international standardisation body has developed a standard, ISO 19119- Geographical Services which is largely based on the principle of open interface specifications. The standard provides a "framework for developers to create software that enables users to access and process geographic data from a variety of sources across a generic computing interface within an open information technology environment" [1]. Open GIS Consortium (OGC), an industry consortium, working in conjunction with ISO are working on a mission to " deliver spatial interface and encoding specifications that are openly and publicly available for global use" [1] . Their vision is to make geographic information and service available across any network, application or platform. A Reference Model has been drawn up by OGC for the task [1]. One of the central area of work by OGC is developing standards for geographic web services or OGC Web Services (OWS). One of the most significant applications of OWS standards is in architecting Geoportals in the context of National Spatial Data Infrastructure (NSDI). The existing international standards and promised future work, holds up a new paradigm of building flexible, scalable, optimal, Open Distributed Geographic Processing Systems both at enterprise, govt and international levels. Chained services hold the key to the promise of providing the full functionality of a GIS on the web.

Currently in relative infancy, the technology of chained services when fully realised will form the backbone of Spatial Data Infrastructures. Given the central common attribute of Distributed Processing, any plans of a future SDI should by all indications be pegged on technology of Geo Web Services to achieve distributed processing, interoperability and ubiquity. The central theme of this thesis is architecting a GDI system to realize it using a combination of these technologies.

The Geoportal which is an internet access point to SDI by its definition is an Open Distributed System (ODP) . Reference Model for Open Distributed Processing (RM-ODP) is an ISO/IEC standard formulated as a framework to capture specifications of ODP systems [3]. It provides an internationally agreed conceptual formalism and specification language to author system specifications. Of an ODP system. Its unique feature is the introduction of five independent viewpoints on the system. The RM-ODP is also adopted by OpenGIS consortium (OGC), pursuing distributed GIS and interoperability. But RM-ODP does not specify a notation or methodology. Its usage has therefore been limited and difficult [4]. UML is a defector modelling language standard for software architecture.

This thesis develops a Reference Architecture for a Marine Geoportal based on the framework of RM-ODP, using the UML modelling language , following a methodology synthesized from a study of the standard , the domain requirements , the modelling language and existing work.

1.2. Motivation

The study is motivated by the need to draw up a Reference Architecture for a marine SDI Geoportal, which serves as a framework for communication between stakeholders and designers as it spirals towards the final architecture. It aids stake holders to present, discuss, and modify requirements and developers to analyse, understand and design the system using common semantics. This abstract away the technology choices and the physical distribution details i.e. a platform independent model of the system. It is a standard practise used in architecting and system development cycle. [5].

This study has aimed to develop a reference architecture of a marine geoportal based on architectural framework of RM-ODP using UML as the modelling language. The aim has been threefold. To develop an reference architecture for a domain (marine) which is less active, less understood in many SDI initiatives and prepare a specification for a marine geoportal in a language that promises to bridge the usual semantic pitfalls between the language of the functional (business) domain and the language of IT system specifications. It was also aimed to create a useful example of the use of [RM-ODP together with UML for an SDI geoportal as very little on this aspect is apparently available. In order to do this a methodology was developed as RM-ODP is methodology independent.

The value addition of this thesis is considered in the possibly unique combination of three aspects - use of RM-ODP with UML for the marine domain. The fourth aspect is the methodology established. Both RM-ODP and Marine SDI have received lesser attention. Further, use of UML with RM-ODP has not been defined. All the three areas have received relatively less attention in this combination which is considered promising for the large marine domain of SDI. Research did not reveal any significant architecture for a marine Geoportal on RM-ODP standards.

The fact that the RM-ODP and UML enable Object oriented programming against the still wide-spread use of relational models and E-R diagrams has another area of significance. The Object helps address both the structural and behavioural aspects together as is necessary for a Services based system.

1.2.1. Architecture and RM-ODP Framework

RM-ODP defines Architecture (of a system) "as a set of rules to define the structure of a system and the interrelationships between its parts" [3]. Distributed processing has grown rapidly. The RM-ODP fulfils a need for a co-ordinating framework for standardizing and action and simplifying architectural specifications of Open Distributed Processing (ODP) System, through a set of five views - Enterprise, Computational, Information, Engineering and Technology. More details are given in chapter 3. Brief definition are given below :-

- The enterprise viewpoint: a viewpoint on the system and its environment that focuses on the purpose, scope and policies for the system.
- The information viewpoint: a viewpoint on the system and its environment that focuses on the semantics of the information and information processing performed.
- The computational viewpoint: a viewpoint on the system and its environment that enables distribution through functional decomposition of the system into objects which interact at interfaces.

1.2.2. SDI and Geoportal

A services based NSDI Geoportal is considered to encompass the following main infrastructure elements of an SDI :–

- A Digital Clearing House providing search based information on all geographical data and services whether online or offline, whether as web services or otherwise.
- Framework Data as a set of selected themes and features which enable cross domain integration of geographical data.
- Access to non-framework geographic and value added data and services.
- Interoperability and Distributed Processing.

The first step of NSDI achieved by several countries notably US, Canada, Australia, Netherlands, has been to set up networks of clearinghouse servers. As a second step they are developing a Geographic Geoportals largely based on OGC Web Services Architecture [6].

1.2.2.1. Among the First Steps towards an SDI Geoportal

Several countries have begun or are well on their way to realizing an SDI . But these are mainly in developed economies. Even here certain sectors like the terrestrial domain has received more attention than the marine counterpart. The need for an SDI is equally important in less developed economies if only to spur the economic growth. Very often the trajectory from original conception to the first tangible step i.e. issue of an RFP is the difficult. Very often it is due to lack of formal communication between various stakeholders, internal architects and prospective developers. An instrument is necessary which models the system allowing them to see what business functions it addresses, through what functionalities, and using what information. This leads to a common understanding and agreement about the system without the complexities of distribution and technology. A Reference Architecture is meant to perform this role.

1.2.2.2. What and Why of Reference Architecture ?

Reference architecture is high level system specification defining its overall target structure. In consistent manner. It frames or bounds choices, ensuring concepts and rules of structure are incorporated into all intermediate solutions spiralling toward a target architecture. An architecture is a more fully specified instance of a reference architecture.

A Reference Architecture is a means of creating a needs specifications by the *enterprise's* architect. It meets the need to specify a business, the system, and placement of the system in the business through the enterprise, information and computation viewpoint. “It is a method that can be used to construct a reference architecture” that is popular today” [5]. Once this is done the distribution system detail and the technologies to use can be left for a contractor to decide. [5]. The reference architecture defines the envisioned target architecture without addressing engineering or technology viewpoints. In other words it is a Platform independent architecture.

This thesis develops a *Reference Architecture* for an NSDI Geoportal based on chained services. This is done from the enterprise perspective of a service-oriented Coast/Marine Geoportal. A Geoportal provides a single point access to data, services and applications through the web.

The Reference Architecture uses the constructs of concepts of RM-ODP. For chained services it instantiates the ISO abstract standards on Services [7]. Where necessary it profiles OGC Standards on Web Services from OGC Reference Model. A profile is defined as, “a set of one or more base standards, and, where applicable, the identification of chosen classes, subsets, options and parameters of those base standards, necessary for addressing a problem area or accomplishing a particular function.” [8].

1.3. Problem Definition

1.3.1. Reference Architecture for a Marine Geoportal

Very broadly, geospatial domains may be classified as terrestrial and marine domains. The terrestrial domain has received more attention in SDI initiatives. With the result progress in the Marine domain has been slow or absent. One initial reason could have been the bandwidth constraints at sea. Also the relatively lesser interface between land and marine data stakeholders compared to intra land domain. But this is changing rapidly particularly with the need to balance ecological considerations with development. We take for example, the areas of Coast Zone Management, Marine Navigation/Ports Management and Marine Science Research /Warning and Prediction. They collect and use data often usable by each other but there is much duplication and little inters operability. A marine NSDI Geoportal will help each information community gain ready access to required data for production and decision support. Also for interchange within the community and across the marine domain. The marine domain has a preponderance of Time Varying Objects (TVOs) - currents, tides, and met parameters. It is also governed by a complex international legal regime.
The Reference Architecture would encompass the user view, information content and its functional decomposition into components. It would first be a discussion document between stakeholders. It could then form part of an RFP calling for a full architecture, which not only adds the engineering and technological views but also refines the Reference Architecture.

To the best of author's knowledge after substantial research through the SDI literature, no Reference Architecture for a marine portal is available in the public domain. It is however known that a Marine portal is under development under the Canadian CGDI program. It was therefore examined how needs specifications for a marine portal can be built using the international standard for architecting ODP systems, RM-ODP [1]. As the standard does not specify any modelling language it is also examined how the formal modelling language UML could be used to develop the architecture.

1.3.2. Why Reference Architecture using RM –ODP

ODP standardisation aims at developing a framework for system specification. Reference Model of Open Distributed Processing (RM-ODP) is an ISO/IEC standard which provides this framework. It has a unique feature in the five viewpoints from which the system is specified to reduce complexity

Haim Kilov an expert and author on RM-ODP has summarised the significance of RM-ODP in [9]. RM-ODP is an internationally agreed comprehensive standard for modelling of open distributed processing systems, which among other things deals with bridging semantic interoperability between business and IT experts. It provides a structured system of common concepts on which patterns of reasoning may be based. It is neutral of syntax, methodology and tool. It semantics concepts required to understand and specify semantics of system components and structure from the existing knowledge base. Within each specifications it provides for separation of concern to reduce complexity. It defines five viewpoints for the purpose. It reduces the number of concepts required by providing a system of interrelated definitional primitives. Up to the refinement desired it defines what should always be true about entities, relationships and processes. The business domain is precisely captured in a language comprising concepts, rules and structures, which are standardized and are easily integrated with the system components specifications as it is specified in the same framework of concepts. [9]

Janis Putman another author on RM-ODP explains the importance of RM-ODP in [2]. Capturing user needs has been a problem due to differences between the languages of the user domain and language of IT. "RM-ODP overcomes this problem by capturing in its enterprise model aspects specific to the business. Further it provides all rules and concepts required to transform these aspects into other models, which are relevant to the system semantic, information and processing. Different areas of focus on the system are described in RM-ODP in a consistent manner such that decision made in one area or focus are reflected in other areas." [2]

1.4. Literature on RM-ODP Use Reviewed

Some ongoing efforts by International Standards bodies and interest groups relevant to this study. There is an ongoing work on standardizing the use of UML with RM-ODP but ISO but it is in draft stage and could not be accessed (www.iso.org). Very limited literature on ODP System architectures using OGC Services, ISO service standards, RM-ODP and UML was found. This was limited to the INSPIRES Architecture and Standards Position Paper on European GDI [10], and a Candidate Portal Architecture at Annex B to RFQ for US Geospatial One Stop Portal [11]. In the former case, it addresses the distribution infrastructure at a macro level. The latter document is a sketchy outline of the geoportal. None of them constitute a Reference Architecture as envisaged in this thesis.

Some general literature on architecting with RM-ODP with some examples was reviewed. Notables ones are mentioned here. A paper from Interoperability Technology Association for Information Processing Japan [4] is an abridged version of a report on using RM-ODP with UML profile for EDOC (Enterprise Distributed Object Computation). This UML profile has been specially adapted for defining RM-ODP architectures for Distributed Enterprise systems. AS UML EDOC was not used the paper was of limited use but gave insights into the relation between RM-ODP concepts and UML. Another paper [2] provides a general approach to applying RM-ODP to describes distributed system using UML as notation. This was also found useful to unbundled the cryptic language of RM-ODP standard and relate it to the real world of architecting. Besides this [9] looks into the use of RM-ODP to bridge communication gaps between stakeholders by providing a common semantic basis. A paper on application of ODP enterprise viewpoint to Hospital Information System [13] was also valuable. An example of applying RM-ODP to a large Swiss bank is explained in [14].

1.5. Survey of NSDI Architectures

NSDI architecture of some nations with advanced GDIs, reveal that they are not based on the RM-ODP Reference model recommended in ISO 19119 [5]. There is however a recognition and mention of the ISO/OGC model based on web services. A reason could be that the RM-ODP appeared only in about 1995.

1.5.1. Canada NSDI

A national initiative to build a Canadian geospatial data infrastructure (CGDI) was funded in 1998. Part of the CGDI programme is a marine GeoPortal. The GeoPortal is intended to be a single point access to all data internal to department of fisheries and oceans Canada. A user interface is being developed. The portal currently provides a browser facility for discovery service, data and chart discovery service for data nautical charts and other maps of the department of fisheries and oceans. The project is still under implementation[1]. It uses specifications developed by ISO/tc211 and OGC. The implementation standards supported by the GeoPortal are OGC WMS, WFS, OGC geodata discovery service, GML, Metadata specification and International Hydrographic Office (IHO) S-57 for Electronic Navigation Chart (ENC).

CGDI architecture recognises RM-ODP as adopted by OGC and ISO standards, but does not adopt it for its architecture description [15].

1.5.2. North Rhine Westphalia Germany SDI

Geodata Infrastructure North Rhine-Westphalia in its Reference model [16] for the GDI follows a three-tiered architecture. At the top is the Business Model and at the bottom the Implementation model. In the centre is a model comprising sub models namely Model of Roles, Process Model and Architecture Model. The Architecture model apparently is a combination of computation and engineering views.

[1] www.geoconnections.org

1.5.3. Australia (ASDI)

Australian SDI is currently not following OGC standards but is moving towards incorporating them. There is reference to this in a summary of Australian spatial data directory and metadata workshop discussions. It is learnt that the OGC Reference Architecture Framework has support within the executive agency of Australian SDI and will probably be used for the development of ASDI[2].

1.5.4. USA (NSDI)

The only instance of RM-ODP usage for a Geoportal was found in this case. A candidate portal architecture for US Geographic One Stop (US GOS) Geoportal, based on RM-ODP was enclosed together with an RFQ calling for a complete architecture based on it, in 2002 [11]. US-GOS includes only simple services. There is only a passing reference to chained Services saying that. Chained services are subject of current research. The US NSDI has set up a clearing house network which shall be incorporated in the Geoportal. In the US NSDI organization which is headed by the Federal Geographic Data Committee, one of the nine sub committees focuses on Marine and Coastal Spatial Data. Any significant literature on its output could not be found.

1.6. Expected Value Addition

In this situation it is expected that examination of how the ISO/OGC standards can be profiled in an RM-ODP based architecture framework using UML, could contribute as a useful example in the marine domain. For those involved in NSDI initiatives as representative of major stakeholders such as NMOs (like the author), this is considered to be of significant value.

The value is three fold – one, provide a non trivial example of architecting an important element of a Marine GDI using the RM-ODP framework, two, in the defector modelling language standard of UML, and three, through a suggested methodology. (It may be recalled that RM-ODP provides neither a modelling standard nor a methodology to approach the problem of using its framework and further of documenting/visualizing it through a modelling technique).

The practical value of the Reference Architecture for a marine geoportal is as a (candidate) reference document for an RFP for a complete architecture. The complete architecture further refines the Reference Architecture and adds the RM-ODP engineering and technology viewpoints to generate a full Marine Portal Architecture Specification document for implementation.

The other significant value of this thesis is the user/business model of part of the marine domain specified, in RM ODP terms and expressed in UML. This is often the most critical and non trivial part of the system specification. It directly impinges on the user application in this case a Geoportal for Geoservices. Its accurate specification is one of the vital needs that RM-ODP fulfils. Specifying the Geoinformatic User requirements in the language of an architectural specification is considered a vital and non trivial task.

2 http://asdd.ga.gov.au/asdd/2004workshop/discussions.html

Finally the research can also be seen in the context of ITC research spearhead 'strengthening civil society' particularly the 'Tested-GDI' program3 which supports the NSDI initiatives of Less Developed Countries, as one of its stated aims.

1.7. Objective

The objective is to create a (candidate) Reference Architecture for a Marine Geoportal, in terms of RM-ODP [3] architecture framework, using UML [17] as the modelling language and to test it for consistency. The following elaborations apply: -

- The Marine SDI Geoportal is treated as a user application providing Geoservices as a profile of existing international standards (ISO/OGC), on Geo web services, with focus on chained services.
- Particular attention shall be paid to capturing user requirements for two reasons. Without subjecting to the rigorous methods of an architectural framework like RM-ODP, the user requirements cannot be captured to the desired accuracy. On their correct determination rests success of the whole Geoportal architecture.

1.8. Research Questions

A Reference Architecture comprises the Enterprise, Computational and Information views of the ODP system. But no methodology is provided in RM-ODP. The central question therefore reduces to - how can the RM-ODP Enterprise, Computational and Information viewpoints be developed for a typical Marine Geoportal and the specification expressed in UML.

To help guide a methodology of building the three viewpoint specifications above, the following research questions have been identified: -

1. For an initial Marine SDI Geoportal, for Less Economically Developed countries what could be the priority areas of concern?
2. What Business Goals, User's requirements, constraints and Processes of the Marine Geoportal can be identified from the standpoint of the User and system environment?
3. How can the requirements at question 2 above, be realized through chained services to satisfy User Requirements.
4. What is the design criteria for modelling chained services?
5. What service framework can be developed for the geoportal as a profile of OSF (OGC Web Services, Service Framework)?

1.9. Outline Research Methodology

1.9.1. General

While the marine geoportal is not restricted to a geographical context, for the purpose of giving a touch of realism in drawing the User Requirements, a representative geographical context was chosen. This context was adopted from the Indian Ocean rim, a fairly large geographical area. The maritime policies and priorities of India, a representative country in this area, were used to develop the RM-ODP Enterprise View. Microsoft Visio UML tool was used to capture architectural constructs in

[3] http://www.itc.nl/research/policy/spearhead1/kraak.asp

UML. Constructs of Geoservice Design Methodology [23] have also been used to strengthen and supplement the process

1.9.2. Phases

- Phase 1 - Review Literature, namely RM-ODP, UML, Services, Open GIS Specifications, Interoperability, Open Distributed Processing Technologies (Overview), Formal Description Techniques, Client/Server Technology, Spatial Data Infrastructure Implementations, process modelling, System analysis and design.
- Phase 2 - Establish the methodology in context of using RM-ODP with UML to develop the architecture.
- Phase 3- Define the Enterprise viewpoint of Geoportal through the Indian context. Choose 4 representative UseCases to span the three typical roles of User, Provider and Broker in a service oriented architecture. Develop one usecase in some detail. Omit these details for remaining.
- Phase 4 –Develop the computational viewpoint on the system focussing on chained services. Establish design criteria for service chains. Map the required services to service taxonomy and OWS Service Framework.
- Phase 5 - Develop the Information viewpoint. Specify sources for a feature catalogue relevant to the Geoportal.
- Phase 6 - Test for consistency using consistency rules of RM-ODP standard.

1.10. Thesis Outline

The thesis has been organised in chapter as shown below.

Chapter 1 is the introductory chapter which introduces the background problem, and the motivation behind the thesis. It also discusses briefly the past work and literature related to the thesis. Finally the objectives, research questions and methodology are outlined.
Chapter 2 outlines the basic concepts of services.
Chapter 3 gives an overview of Reference Model of Open Distributed System (ISO/IEC RM-ODP) standard for architecture specifications. It goes on to establish a methodology of capturing the architecture and depicting it in UML.
Chapter 4 captures the top level Enterprise view of the marine Geoportal. Mainly the major areas of concern, four usecases, and policies are identified. The Usecases are further developed in subsequent chapters.
Chapter 5 deals with the Usecase Fisheries Advisory Service. All three views enterprise, Computational and Information are developed in some detail. Criteria for service chaining is also addressed here.
Chapter 6 tests the consistency of the architectural specifications developed in previous chapter.
Chapter 7 continues with the remaining three usecases and develops the Enterprise and Computation and information views. These are limited to diagrammatic representation based on the same methodology used in chapter 5.
Chapter 8 concludes and offers some observations.

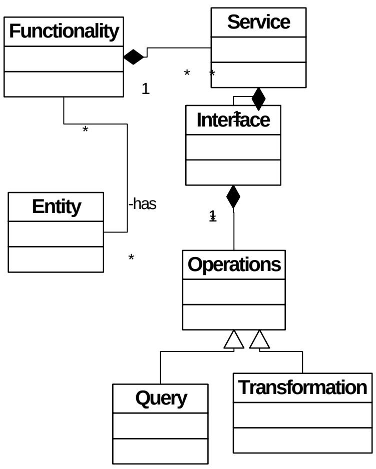
Introduction to Services

As the primary entity which realises a Service Oriented ODP system, is the *service*, this chapter is introduced to cover some basics of services. The services employed in this architecture are a profile of OGC specifications on Web Services referenced in the OGC Reference Model [1]. Where no suitable is found for a required service, the services specified in ISO standard ISO 19119 [7] has been adopted.

2.1. Basic Definitions

Basic definitions from OGC Reference model [1] to construct a service model are given below as also illustrated in figure 2.1 below :-

- *Service* : Distinct part of functionality that is provided by an entity through interfaces.
- *Interface* : named set of operations that characterise the behaviour of an entity.
- *Operation:* Specification of a transformation or query that an object may be called to execute . Each operation has name and a list of parameters.



Another useful definition can be found in OGC Web Architecture Discussion paper [6]. “Useful/meaningful combination of operational interfaces and accessible content”. The addition of content in the definition of service is said to be unique to web services in the spatial domain.

Figure 2.1 **Meta Model of the basic elements of geographic service**

2.2. User/Provider/BrokerRoles and Publish/Find/Bind Pattern

Central to the architecture of a services based system are the three basic roles of user, provider and broker of services as shown in figure 2.2 below. Analogous to each role are the three operations of publish, find and bind. They support dynamic binding between service requestor and service broker.

Separation of content and presentation is another characteristic of services. The information model of service content becomes accessible through service interfaces by means of data encoding. Encoding alternatives are XML and XML schema.

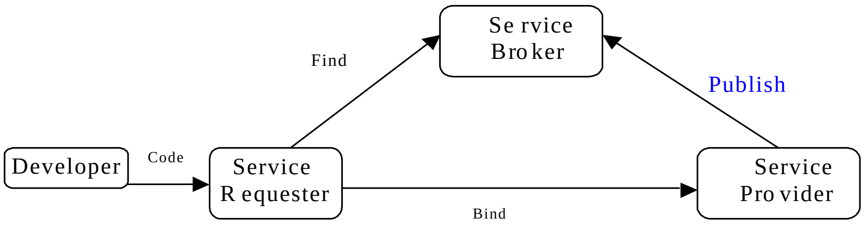


Figure 2.2 Publish Find Bind Pattern

2.3. OWS Service Framework (OSF)

The Service Oriented Architecture has been adapted for geospatial services by the OGC in the Open GIS Web Services Service framework (OSF) which specifies services, interfaces and exchange protocols utilisable by any application [1]. OpenGIS Services are implementations of services that conform to OpenGIS Implementation Specifications Compliant applications, called OpenGIS applications, can then plug into the framework to join the operational environment. A figure defining the conceptual framework of OSF is placed at Appendix A – Chained Services – More Details.

2.4. Service Chains

2.4.1. What is a Service Chain

As single services are very often not sufficient to execute all but the most atomic tasks, service chains are necessary to do so.. A service chain is defined in ISO standards [7], as a sequence of services where, for each adjacent pair of services, occurrence of the first action is necessary for the occurrence of the second action. The same standard states that combining services in service chains is key to meeting the geographic needs. Service chaining is expected to allow user defined combinations of data and services to achieve bigger tasks not achievable by single services. This achieves one of the primary purposes of Distributed Systems. Service chaining is a specialisation of Processing Services in the Semantic Classification of OGC Reference model.

Figure 2.4 Depicts a generalised model of Chained Service

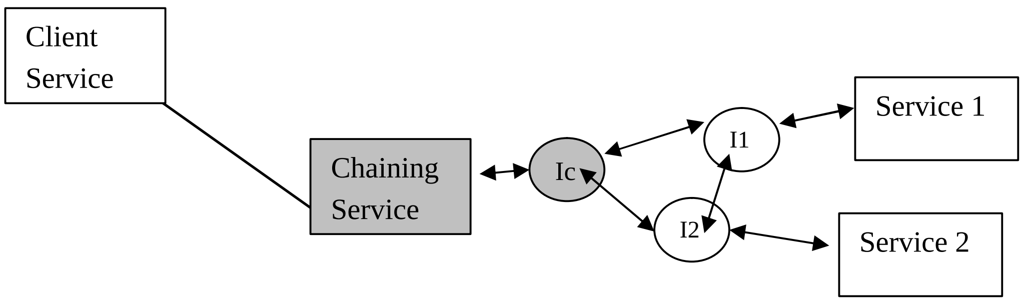


Fig 2.4 shown above is a generic model of a service chain where the circles depict the interfaces associated with each service. The interface Ic of the Chaining service is executing the service chain comprising service 1 and service 2.

Unforeseen tasks or those not supported directly by existing atomic services can be executed by service chains. They enable user defined data and service combinations those not defined by providers. OGC envisions, user having the means to map loosely coupled services to suitable data, define and execute the chains. In the initial stages however, service catalogues will most likely contain tightly coupled services. [7].

2.4.2. Three Types of Service Chains

There are three kinds of service chaining.

- User Defined (Transparent) Chaining . Flow is managed by the human user.

- Workflow Managed (Translucent) Chaining. A Workflow management service is invoked by the human user. Workflow svc controls the chain but user is aware of services in the chain and intermediate results.
- Aggregate (Opaque) Service. The user invokes a service which executes a chain. User has no awareness of services in the chain.

More details of the three types of service chains mentioned above are placed at Appendix A.

2.5. Service Categories

Three classifications of services have been defined in OGC Ref model [1]- Semantic, Interface and Capability classification.

2.5.1. Semantic Classification (using a service taxonomy)

This is a semantic categorisation to enable browsing by category of desired functionality [1]. The following categories are defined in OSF :-

- Application Client Services. These are the client side components of client applications which interact with users, and on the server side interact with server side client applications., applications servers and a data servers. . These are of service type Human Interaction Services as defined in ISO standard 19119 on services [7] .
- Registry Services Provides a common mechanism to classify, register, describe, search, maintain and access information about network resources (data and services) (OWS Web architecture)
- Data Services . The foundational service building blocks that serve data, specially geospatila data
- Portrayal Services . They provide specialised capabilities supporting visualisation of geospatial information. They are components that , given one or more inputs , , produce rendered outputs such as cartographically portrayed maps, perspective views of terrain , annotated images , views of dynamically changing features in space and time etc.
- Processing Services . The foundational application building block services that operate on geospatial data and metadata, providing value add service.

More details about interface and capability classification may be found in Appendix A.

2.6. Conclusion

After this brief survey of the basics of services and service chains, the Architecture framework standard of RM-ODP and UML are introduced in the next chapter. An outline methodology of employing RM-ODP to specify the architecture for the chosen application area of Marine Geoportal is also presented.

3. Basic RM-ODP and methodology of modelling using UML

This chapter introduces the basic principles of the standard Reference Model of Open Distributed Processing [3] . Next the Universal Modelling Language (UML) is defined. This is followed by a methodology adopted for specifying a candidate Reference Architecture for a simplified Marine SDI Geoportal. The methodology uses the 'patterns of reasoning' enabled by the architectural concepts of RM-ODP. and the notational formalism of UML.

In section 3.3 dealing with computational viewpoint some design principles behind chaining of services are also outlined.

The Reference Model of Open Distributed Processing, [3] is in four parts :-

- Part 1 (reference) contains an overview.
- Part 2 (foundations) defines concepts and terms.
- Part 3 (Architecture) defines the concepts used in each viewpoint language and the rules and structures to specify the viewpoint in that language.
- Part 4(Architectural Semantics) complements parts 2 and 3. Interprets modelling concepts and viewpoint languages in terms of existing formal description techniques.

3.1. Thumbnail sketch of RM-ODP

3.1.1. General Overview

Distributed processing has grown rapidly. The RM-ODP fulfils a need for a co-ordinating framework for the standardization of Open Distributed Processing systems.. It provides a paradigm to develop an architecture wherein distribution, interworking, flexibility and portability can be integrated. ODP standardization addresses distributed systems across boundaries of multiple organizations and technologies. Being federated systems they exhibit characteristics like autonomy, heterogeneity, mobility. To allow for these the ODP design standardization aims to include the attributes of openness, modularity, flexibility, provision of quality of service, security. ODP system are describable in terms of interacting objects. [12]. ODP standardization aims at enabling distributed information processing services in a environment of disparate IT and organizational domains. This particularly applies to creating an SDI using such disparate resources. There are some basic characteristics of distributed systems. Two notable ones are :-

- *Remoteness*: distributed system's components may spatially distributed, interactions might be local or remote.
- *Asynchrony*: No single global clock drives communication and processing activities. Related changes in the system cannot be assumed to occur concurrently.

The RM-ODP provides the framework and enables *ODP standards* to be developed specifying components that are mutually consistent and can be combined to build infrastructures matched to user requirements. Complying with ODP architectural principles and conforming to ODP standards in the construction of distributed systems will result in open distributed systems. The RM-ODP simplifies the process of specifying complex systems by dividing the ODP system specification into *view-points*. A viewpoint is defined in RM ODP as " an abstraction that provides a specification of the complete system related to a specific set of concerns". In order to express these viewpoints a viewpoint language is defined. The viewpoint language comprises concepts relevant to a particular area of concern . The concepts are *basic modelling concepts. Specification concepts and structuring concepts.* The basic modelling concepts are concerned with existence and activity: the expression of what exists, where it is and what it does eg object, environment, interface, behaviour. They define the object model adopted by RM- ODP. The specification modelling concepts deal with the requirements of specification language and include terms like composition, decomposition, type, subtype, roles etc. The structuring concepts refer to architectural structures in the ODP system and include group, name, domain. In addition for each language there are rules which constrain the corresponding viewpoint specification.

The five RM-ODP viewpoints are defined as follows :-

- *Enterprise Viewpoint*: a viewpoint on the system and its environment that focuses on the purpose, scope and policies for the system.
- *Information Viewpoint*: a viewpoint on the system and its environment that focuses on the semantics of the information and information processing performed.
- *Computational Viewpoint*: a viewpoint on the system and its environment that enables distribution through functional decomposition of the system into objects which interact at interfaces.
- *Engineering Viewpoint*: a viewpoint on the system and its environment that focuses on the mechanisms and functions required to support distributed interaction between objects in the system.
- *Technology Viewpoint*: a viewpoint on the system and its environment that focuses on the choice of technology in that system.

The scope of this thesis spans the Enterprise, Information and Computational viewpoints only. Using these it is intended to create a Reference Architecture which, is implementation independent, focuses on a target system, and has the primary aim of communication between stakeholders towards iterative refinement before contracting a complete architecture.

3.1.2. Concepts in different Viewpoint Languages

The languages are defined as comprising of concepts, rules and structures for specifying an ODP system from the corresponding viewpoint. Some of the concepts are listed below. Their definitions may be found in the Glossary .

The modelling concepts defined in RM-ODP are put into six categories. Basic interpretation concept, basic linguistic concepts, basic modelling concepts, structuring concepts and conformance concepts. Combination of these concepts are associated with each viewpoint language as shown in subsequent sections.

3.1.3. Enterprise Language

It contains the following concepts :-

- Community

- Federation.

3.1.4. Information Language

The main concepts used in this language are:-

- Invariant schema
- Static schema
- Dynamic schema

3.1.5. Computational Language

- Signal
- Operation
- Announcement
- Interrogation
- Flow
- Signal interface
- Operation interface
- Interaction
- Interface
- Stream interface
- Computational object template
- Computational interface template
- Signal interface signature
- Operation interface signature
- announcement signature.
- interrogation signature
- Stream interface signature
- Binding object

3.2. UML

RM-ODP standards available since 1995 have not been used extensively. This may be partly ascribed to the fact that they focus on concepts and rules for distributed applications, but do not specify a methodology or notation or to provide flexibility. But it did not help the ordinary user [4]. UML specified by OMG, is the defector standard for modelling software systems. UML standing for Unified Modelling Language is a set of modelling tools to specify, visualize, construct and document models of software systems, including their structure and design. UML has been used as the modelling language to describe the viewpoint specifications. Further its modelling tools have been used to define an approach to model development. Following is a brief description of six types of UML diagrams used [17].

- Use Case Diagrams. Describe what a system does from the perspective of an external observer.
- Class Diagrams . Gives an overview of a system by showing its classes and their relationships. They are static diagrams and display what interacts not what happens when they interact.
- Sequence Diagrams . They describe how objects interact. They are dynamic.

- Collaboration Diagram. They are also interaction diagrams but focus on object roles rather than on timing of messages.
- State chart Diagram. It shows the possible states of the object and transitions that cause a change in state.

3.3. Methodology Used

Methodology consists of a development process, containing a set of activities that result in a set of specifications [12]. These specifications are described primarily in terms of models in UML diagrams backed up by prose text and sketches. A model is a formal specification of the structure and/or function of a system.

The methodology in this thesis is based on modelling the system in terms of OMG Model Driven Architecture (MDA) . It defines a platform independent model as “a formal specification of the structure and function of the system that abstracts away details of technology” [18]. This model is further seen as comprising two sub models – the Use Case Model and Analysis Model after the Unified Process [18]. The Use Case model captures the system requirements from user’s perspective and the external environment. The Analysis Model captures Classes required for use case realisation is developed. [19]. Figure 3.1 illustrates the model hierarchy. (It is clarified that the Unified Process is not deployed beyond borrowing the concept of the two models. The two models could also be called as Business model and System functionality Model.

The Use case model is developed using the enterprise viewpoint specification. The analysis model is built through information and computational viewpoint specifications. While [5], [4], [7], [12], [9], [13], [14] were found very useful in sharpening the edges of understanding, this methodology has been developed from a combination of the primary sources i.e. the architecture standard RM-ODP [1], needs of the Marine Geoportal and the rules/concepts of UML [17].

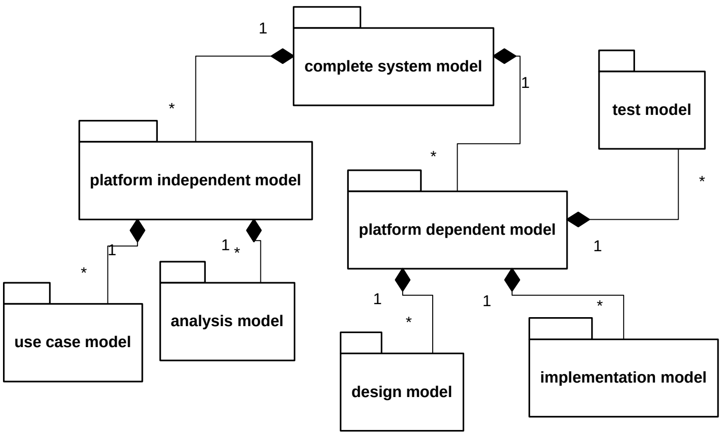


Figure 3.1 Model Hierarchy Diagram

3.3.1. Enterprise Viewpoint

The enterprise viewpoint: a viewpoint on the system and its environment that focuses on the purpose, scope and policies for the system. An enterprise specification is based on enterprise objects (and their roles), belonging to a community of enterprise objects which comprise the enterprise. A key concept is contract. It links roles in communities and indicates their obligations.[12]. The methodology adopted is given below.

3.3.1.1. Areas of Concern

Identify Areas of Concern to be targeted and the system environment. Denote it in a sketch.

3.3.1.2. Purpose

Identify Purpose of the Geoportal in terms of desired improvements to existing situation, broad customer needs.

3.3.1.3. Scope

- Identify Scope of the Geoportal in terms of high level functional area and users. Capture them as Usecases, actors and roles in a Usecase diagram.
- For each Usecase identify the participants and their actions. Participants are entities (human, software or system). This may be done by making a sequence diagram for each Usecase.

3.3.1.4. Roles

- Tabulate roles and their actions for each Usecase. Its simplified definition is a “formal parameter providing an identifier for a functioning part of the community behaviour” [5]
- Assign objects to each role. This process can be facilitate by checking each role in the context of process steps, if they have states. Further objects can be identified independently by assigning them one or more roles. A similar approach but not identical has also been taken in [4].
- Enterprise Objects to which those states belong are identified. Refine the list of Enterprise objects and roles.
- Examine interaction between roles in terms of action/s without concern about the actual interfaces and information shared.

3.3.1.5. Business Process

Business Process is defined as a set of one or more linked procedures or activities which collectively realize a business objective or policy goal, normally within the context of an organizational structure defining functional roles and relationships. In RM-ODP business process can be constituted from one or more activities. RM-ODP defines activities as “a single-headed directed a cyclic graph of actions, where occurrence of each action in the graph is made possible by the occurrence of all immediately preceding actions (i.e. by all adjacent actions which are closer to the head).” [1][b]. The atomic unit of activity is action. Actions can be captured as interactions between role based objects

Define business processes for each Usecase . Where necessary the process model shall be shown at two levels of abstraction where one is not considered sufficient to proceed further with the architecture. It is captured employing UML Activity Diagram.

Define Pre and post conditions for each process.

Capture enterprise objects in an object model depicted as a UML Object diagram.

3.3.1.6. Community

Identify communities and depict them as package diagrams or Class diagrams with *Composition*.

3.3.1.7. Policies

Identify policies and denote them as class diagrams showing their hierarchy with stereotypes - obligation, authorization, permission, and prohibition.

Map the policies identified above into our UML based model. Associate them with communities, roles , objects or process steps as notes or constraints.

Identify the **Non functional requirements** , i.e. those not directly related to system functionalities, are specified using prose. These are reliability, availability, security and performance requirements. Captured using prose.

Capture **External Constraints** in prose. These are conditions, decisions, rules which may impact on system development.

Quality of Service. Capture in prose.

Environment Contract . Capture in prose.

3.3.1.8. Remarks

While the specification says the viewpoints are not layered and need not be captured in a predefined order, it was found that for a new system it is logical to first capture the enterprise viewpoint as it deals with the user/business requirements which must govern the remaining viewpoints.

We have identified the scope, objectives, enterprise objects, business processes, actions, and policies and other constraints in the enterprise view point. The software functionalities required shall be realized by services which is the subject of the next viewpoint i.e. the computational viewpoint.

3.3.2. Computational View

This is the viewpoint on the system and its environment that enables distribution through functional decomposition of the system into objects which interact at interfaces.

This is the most important viewpoint for the purpose of our Reference Architecture for Service Oriented Marine Geoportal. IN the context of web services this viewpoint has been described "that concerned with the interaction patterns between the components (services) of the system , described through their interfaces. A computational specification of a service is a model of the service interface seen from a client, and the potential set of other services that this service requires to have available, with the interacting services described as sources and sinks of information" [7]. The Computation viewpoint captures the components and interface details without regard to distribution which is addressed in the engineering view point.

To enable every enterprise object to provide its functionality, the system is viewed here in terms of its software components. The viewpoint specifies Software subsystem boundaries in terms of Application Programme Interfaces (APIs). The concept of function focuses on interactions between interfaces ignoring its implementation. The functional structure is defined by all service compositions and service interactions necessary to provide the system functionality .

3.3.2.1. Capturing Service Oriented Architecture as Computational Viewpoint

The system is modelled as a set of Services to meet the User requirements identified in the enterprise view. The system is decomposed into computational objects at an atomic level, which are chained together to execute the business processes.

We first identify the tasks required to be performed, the actions in the business processes, as captured in UML Activity diagrams. Subsequently the description of Services required and service components that offer these services are identified.

The service components carry out the role of executing task/s. They can be specified by specifying their corresponding interfaces and interactions. Interactions denote that part of action/s associated with an object (component) which takes place in collaboration with other objects [3]. These interactions together with internal actions form the behaviour of these service components. Interfaces are independent of collaborations.

3.3.2.2. The Method

The methodology followed to capture this viewpoint for the purpose of the Reference Architecture is as follows :

- Identify tasks requiring automation by examining the usecase diagram and activity diagram representing the usecases and business-process model respectively, in the enterprise view. Prepare a list of these tasks.
- Identify service *components* that are capable of executing the tasks singly or as chains.
- Capture the architectural patterns[4] of the services chains. The set of component services is identified, their responsibilities specified, and rules and guidelines for organizing the relationships between them laid down. (ISO 19119).
- A service component in its role of being responsible for a specified task or tasks, can be described in terms of its Collaborations, interactions and interfaces.
- Collaborations are how the component in fulfilling its role co-operates with other service components eg in service chains. This is captured in UML Collaboration diagrams.
- Interactions depict the service components' interactions with its collaborators.
- These are captured as UML Sequence diagrams.
- Interfaces denote the protocols related to the component. They are captured as UML classes.

Capturing Service chains has been central to computational view for the purpose of this thesis. The next section outlines some modelling criteria for modelling Service chains .

[4] An architectural pattern expresses a fundamental structural organization or schema for software services. (ISO 19119)

3.3.2.3. Criteria for Service Chains Modelling

Several design criteria can be identified and compiled for modelling a service chain. Some are related to principles of architecting. Others have to do with the desired nature of chaining. Some architectural considerations are listed below :-

(1) Architectural

- Basic Modelling concept of Composition and Decomposition.
- Decompose components associated with multiple functionalities.
- Where some components are associated with small functionalities they can be composed with other components. (merged)
- Common service chains must be identified for reuse.

(2) Directed Acyclic Graph.

Service chains are modelled as Directed Acyclic Graph as input to a service is dependent on output of another service. A node in the directed graph is a service. The node contains service's configuration for the chain and input source to the node. The components are listed, functionally analysed and normalized The collaborations between the services are captured in a UML collaboration diagram. (ISO 19119). The parameters or service configuration may or may not be alterable. Service chains can be parallel or serial. In parallel chains parallel paths based on branches are allowed. A node may operate as an iteration eg DO While.

(3) Type of Chaining Required .

With reference to the type of service chains defined in chapter 2 , another important factor in modelling chains is the chain type desired which depends on the following criteria [7] , [3] , [20] :-

- Degree of transparency required by the client to the service chain.
- Need for client to track data sources and transformations .
- Keeping track of metadata.
- Handling and reporting errors along the chain.
- User expertise and knowledge about how to combine services.
- Ability of user to design a chain that will execute.
- Semantic validity of the chain .
- Availability of a predefined chain
- Nesting of chains
- Recursion of chains with opaque chains as interface.
- Construction of chain by iterative use of transparent chains
- Static chaining services have the disadvantage that the user is unaware of the assumptions and transformations made. It is not easy to discover the location of exceptions if any.

3.3.3. Information Viewpoint

This is a viewpoint on the system and its environment that focuses on the semantics of the information and information processing performed. This specification involves 'componentisation of information model'. The information objects are identified by an examination of the business processes

Information objects may be behavioural objects in the sense that they will actively participate in interactions.. These objects may be detected in service interaction specifications.

3.3.3.1. Method

The following methodology was adopted :-

- Examine each step in a business process. For every step in the business process information objects of four types are identified - Inputs (type and value) , Outputs (type and value), Resources (instance info or state), System Control info
- Examine interactions between services in the computational viewpoint, which are sources and sinks of these objects.

Organise these Information objects in UML Class diagrams which captures the properties (associations and attributes) and constraints (invariants).

- Describe the following schemata as applicable :-
  - **Invariant Schema**. The structure common to every contract between the customers, users and providers is specified as an invariant schema in RM-ODP. It is a set of properties of one or more objects that remain constant as information objects change states. They constrain the possible states and state changes of the relevant objects. Leads to precondition statements. The schema specifies types of objects which are satisfied by any behaviour of the objects. This is captured in text and UML notes.
  - **Static Schema**. It specifies the state of information objects, at some instance in time, subject to the constraints of invariant schemata as applicable. These types of information objects are subtypes of those specified in the invariant schema.
  - **Dynamic Schema.** It is specification of the state changes permitted for one or more information objects, subject to constraints of any invariant schemata. It helps model behaviour in the information system , as transitions from one static schema to another. This is captured in UML state chart diagram
  - With respect to Services capture the Service Metadata describing the capabilities and content of service components in the architecture.

3.4. Concluding Remarks

We have outlined RM-ODP, introduced UML and adopted a methodology of using RM-ODP to architect the reference architecture for the Marine Geoportal. It is highlighted that RM-ODP only provides patterns of reasoning or a logical paradigm to develop architectures for ODP systems. How and in which order to employ its various concepts and rules is not defined. Nor is a modelling language specified in which to express the different models created using the viewpoint languages. While this does makes for flexibility, it leads to difficulties of semantics. UML has been used as the modelling language as it has become the de facto standard tool for software architecting. In the next chapter we develop the initial aspects Enterprise view of the geoportal. The view is continued to be developed in the next two chapters.

4. The Marine Geo-portal – Enterprise View

This chapter specifies the Enterprise View of the Marine SDI Geoportal using the methodology described in Chapter 3. Only those elements which apply broadly to the entire system are addressed in this chapter. Thereafter, Chapter 5 continues with all the viewpoints comprising a Reference Architecture namely Enterprise, Computational and Information for one selected usecase. This is the Fisheries Advisory Services Usecase which is treated in more detail as feasible. In the subsequent chapter (chapter 6), Consistency Test for the chosen Usecase is presented. The remaining Uses cases are treated in Chapter 7 in brief.

4.1. The Marine Domain Defined - Areas of Concern

The Universe of Discourse (UoD) can be taken as the superset of all objects at different levels of abstraction, with their current and potential relationships, defined by geoinformation on sea surface, sub surface, the water column, the coast and oceanic weather. The key areas of concern in this Universe of Discourse are identified next.

Information published by leading international regulatory and advisory bodies working in the marine sector was reviewed. The International Hydrographic Organisation, a UN recognized body of national agencies responsible for charting the seas and coast, has defined major areas of concern in the marine sector [21]. To this may be added some additional areas identified by International Oceanographic Commission (IOC) a UN body [5]. The IOC helps governments to address individual and multilateral ocean and coastal problems. Further, a few more areas may be added like Tourism, Defence and submarine cable/pipe laying. The resultant list below is considered to cover the area of concern in the marine sector very closely :-

- Efficient and Safe Maritime Transport
- Coastal Zone Management
- Exploration and Exploitation of Marine Resources
- Fishing and Ecosystems
- Environment Protection and Management
- Climate Change
- Ocean Observing and Monitoring
- Disaster Mitigation
- Maritime Defence
- Tourism
- Submarine Cable/pipeline Laying
- Maritime Boundary Delimitation
- Marine Science

[5] www.ioc.unesco.org

An NSDI to address all areas all at once is not practical. NSDIs are architected according to national or local priorities. Some priority areas are normally identified and the first Reference Architecture is specified around those areas. For instance European SDI initiative was driven by the need for spatially linked data for environmental clearances [10]. Similarly in Australia the motive force was information on land cadastre in a complex pattern of land ownership [6]. A survey of Marine SDI programs in USA, Canada, Europe and UK [20], also reveals that the strategy has been to develop the SDI around one or two core area and to expand it along the lines of social or developmental priorities.

This architecture likewise restricts itself to a few areas of concern. These may be likened to a sample data set for this purpose. Selection of the sample areas is guided by development and economic priorities linked to the ocean and coast in India (please see Methodology in Chapter 1). India is representative of a large geographical area of the Indian Ocean littoral and of economically developing countries. It offers a good sample because it deals with issues on a sub-continental scale. Although the process of identifying the priority areas is not central to this thesis, an attempt has been made to select them realistically based on published information by competent national, international, and UN agencies. Years of personal experience has also been helpful. Based on the prioritisation, the target marine geoportal is identified to address the following areas of concern :-

- Geoinformation Services for Exploitation of Hydrocarbons.
- Coastal Zone Management - Infrastructure Development
- Weather Forecast Service
- Support Services to Fisheries

4.1.1. Geoinformation Services for Exploitation of Hydrocarbons.

India’s domestic production of crude oil meets only 30% percent of the requirement. In the efforts to give a fillip to domestic production seabed exploration plays a vital role. [22]

4.1.2. Coastal Zone Management - Infrastructure Development

This is a priority for any developing economy. Ports are particularly important. Ninety percent of India’s trade volume is moved by sea. The port sector has been thrown open to the private sector to improve efficiencies and productivity [22] . But the resultant development activity needs to be regulated in accordance with the Indian Coastal Zone Regulation Legislation for which synthesis of multisource coastal geo-information is necessary.

4.1.3. Weather Forecast Service

Like many developing economies agriculture is the life blood of Indian economy. It contributes about 25% of GDP and it is the livelihood of about 70% of the population [22]. Since irrigation is mostly rain fed, monsoon forecast is a crucial area to be addressed. Forecasting is largely dependent on ocean observation data. Accurate prediction of the monsoons is a priority for our scientific community

[6] (http://asdd.ga.gov.au/asdd/2004workshop/discussions.html

4.1.4. Decision Support to Fishing Operations

Fish is staple food for a large section of the population. It is a significant source of foreign exchange, a very important food supplement and employment generator. India is the third largest producer of fish [22].

4.2. Purpose of the Geoportal

With reference to [3] , the *Community* has been depicted in figure 4.1 below. The entities in rounded rectangles are enterprise objects external to the geoportal. Considering the Geoportal as an enterprise object in this community, the purpose of the Geoportal system can be identified.

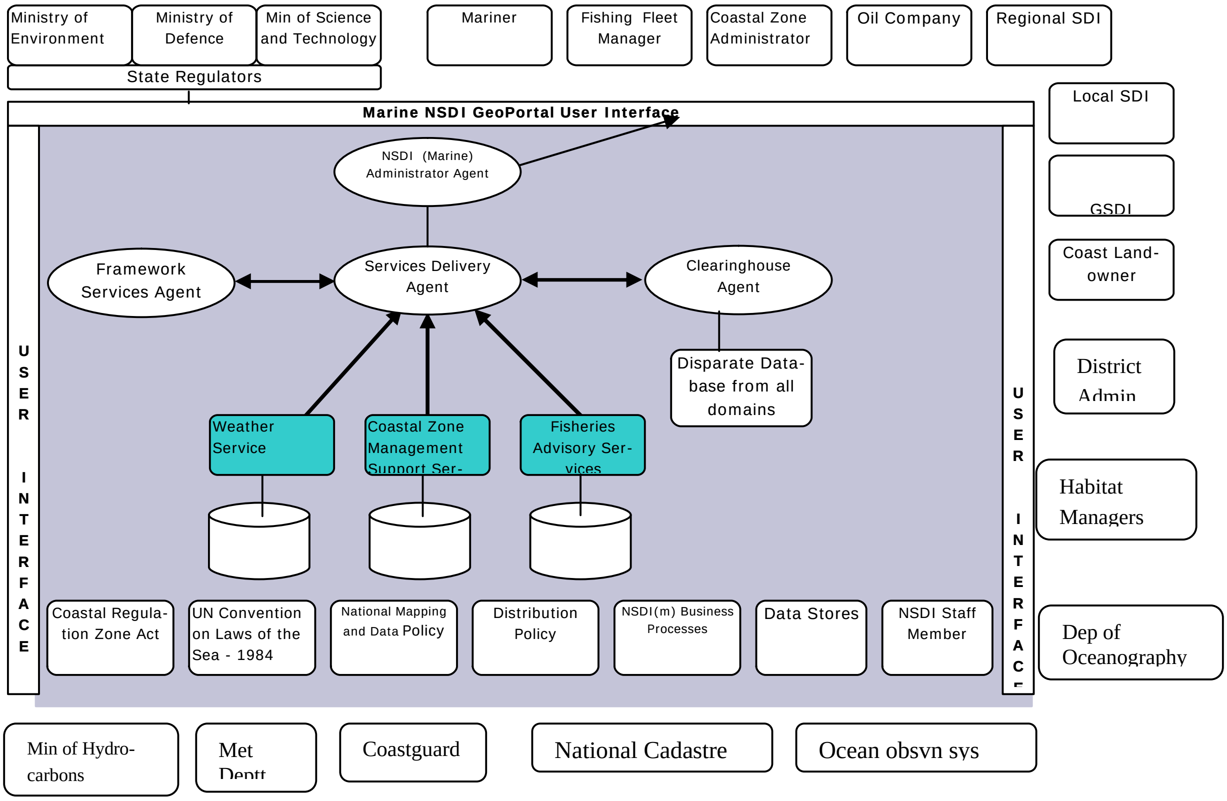


Figure 4.1 Marine GeoPortal - Community View - An Informal Representation

In general the purpose is to provide a Geoinformatics tool for spatially informed decision making by administrators and managers in the marine sector, within constraints of national legislation and international conventions, to help optimize economic activities. This is to be achieved by facilitating provision of geoservices and applications by providers and consumption by users through a single-point standards-based mechanism over the internet. The specific purposes of the Geoportal are listed below :-

- Increase fisheries yield by providing Geoinformation Services and Decision Support to fishermen.
- Geoinformation Service enabled Decision support to managers involved in offshore hydrocarbon exploration and exploitation .
- Speedy Decision making by Coastal Zone Managers on proposals for Coastal Infrastructure, specially new ports and fishing harbours.
- More accurate and timely marine weather forecasts and warnings.

- Making GIS tools available as modules, for visualisation and analysis, to lay persons with no access to monolithic GIS software, particularly to :-
    - Coastal landowner
    - Local executor of the Coastal Zone Regulation Plan
    - Small to Medium Fisherman
- Data synthesis between coastal and shore data.
    - Land reclamation
    - Pipeline route determination from offshore platform to near shore facility.
    - Mitigation from storm surge
    - Cadastral level maps for implementation of Coastal Regulation Zone (CRZ) plans.
- Align and integrate existing local/sectoral geoinformation projects towards seamless operation through the portal.

4.3. Scope of the Geoportal

The scope is to provide marine geoservices to support Coastal Zone Management, Fisheries, Hydrocarbon prospecting and production and Delivery of Weather forecasts. The scope of the system is captured in terms of usecases and actors in the top level use case diagram in figure 4.2 below. The Usecases cater to all the three roles of user, provider and broker.

The hydrocarbon support service has been shown in the top level usecase diagram as a role of the top level usecase hydrographic services which includes framework services for the geoportal, navigation safety services, and other hydrographic thematic data services.

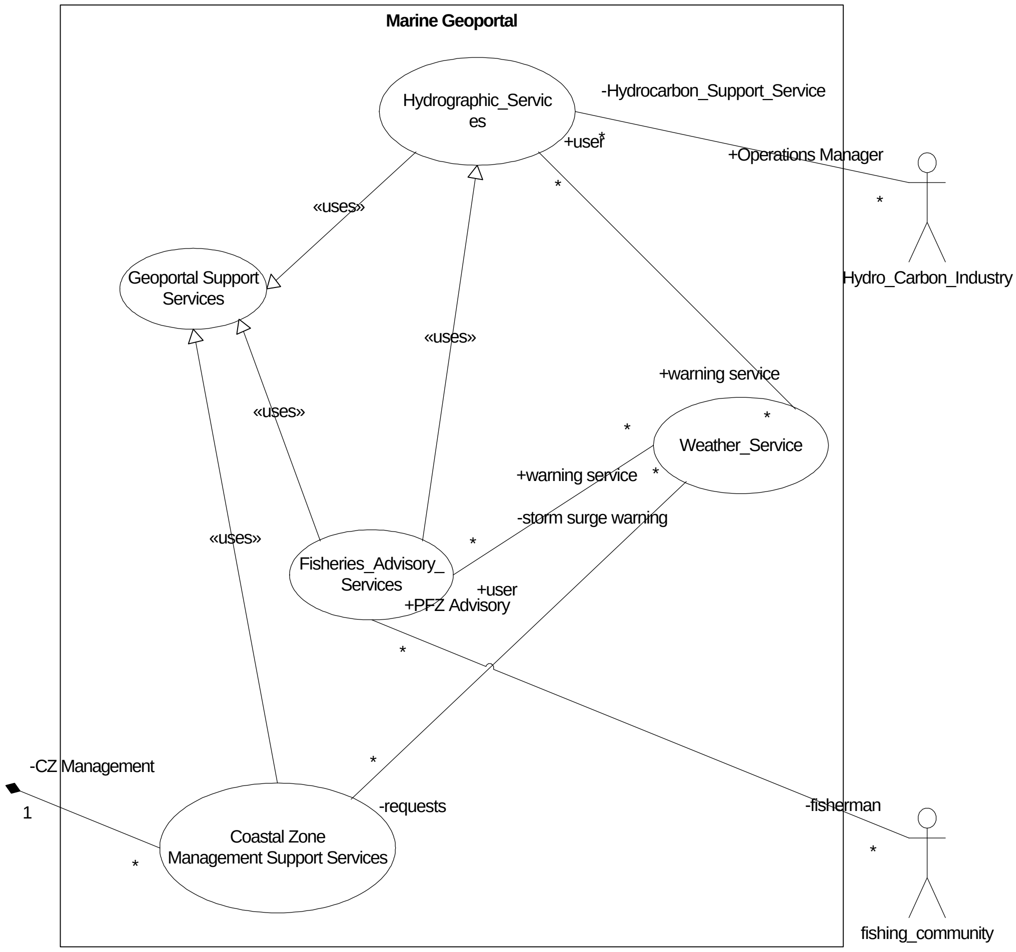
The rest of the enterprise view of the geoportal is continued in the following chapters from 5 to 7. Fisheries Advisory Usecase has been attempted in some detail in the next chapter. This is followed by consistency test on this usecase in chapter 6. The remaining Usecases are treated in chapter 7.

4.4. Quality of Service

The following QoS criteria are specified :-

- Potential Fisheries Zone (PFZ) Data is not more than 2 days old.
- Priority is accorded to Weather warning service, navigation service, and PFZ service in that order.
- During cyclones and other severe weather conditions real-time push-type weather services will be provided.
- The services considered are asynchronous.
- A proximity alarm should be set off if the fisherman is within half a mile of an international boundary.
- Services should be timed out if not realised within a period to be specified the implementation stage.

Figure 4.2 Marine Geoportal - Top Level Usecase Diagram



4.5. Concluding Remarks

In this chapter the user perspective of the Geoportal has been captured using the concepts of the RM-ODP Enterprise language. The system's overall purpose is captured. Also modelled is its scope that is what its constituent real world entities and the system as a whole are to accomplish. Also defined are the rules related to the systems purposes, in other words policies. The system was analysed by identifying the functionalities required expressed as usecases. From these roles and their actions were identified. From these roles enterprise objects are identified. The behaviour defined by a sequence of actions , of these objects were captured as processes in UML activity diagrams.

In the next chapter the usecase of Fisheries Advisory Service has been taken up in some more detail. All the three views comprising a reference architecture i.e. Enterprise, Information and Computational views are captured.

5. Usecase - Fisheries Advisory Services

This chapter develops the Reference architecture for the Fisheries Advisory Services Usecase. This is a representative usecase which is important for any coastal state and expected to be a vital element of any Marine geoportal in this or similar form.

5.1. Enterprise Viewpoint

5.1.1. Background

One key ocean resource is fisheries specially for a populous state such as India. A website[7] of the Department of Ocean Development in India provides information on Potential Zones of Fish Availability, or Potential Fisheries Zones (PFZ). The information comprises the position of PFZ, depth and directions from different fishing harbours, in a tabular form. PFZ forecasts are made based primarily on satellite observations of SST and chlorophyll and in suit surveys by Fisheries Survey of India. The web site also provides sea state data, wind vectors, and currents none of which can be correlated with the PFZ Advisory or any framework data.

Fishermen take their decisions on where to find fish based on traditional methods like rising bubbles, sea-colour, known obstructions, presence of eddies etc. These are not always optimal at best. Also they are often ill informed to follow area-based conservation restrictions. Additionally they very often stray into waters of neighbouring countries and are often apprehended causing hardship to the men and embarrassment to the government.

Further they should be able to receive timely weather and navigational warnings which could be correlated with fishing related information. There is a need to provide all these information so that it can be correlated and synthesized by the fisherman for decision making.

5.1.2. Objective

In pursuit of a marine extension of SDI to strengthen civil society, the objective of the Fisheries Advisory Service is to provide PFZ information correlated with all other geospatial information required by the crew of a fishing vessel, to help improve the fish yield without compromising on safety, observance of maritime boundaries, conservation and environmental laws.

5.1.3. Scope

It is intended to provide the following functionalities to a fisherman of small and medium size with a thin client :-

- Information on Potential Fisheries Zones (PFZ) issued by Department of Ocean Development .
- Routes to selected points.
- Conservation constraints

[7] http://www.incois.gov.in

- Legal constraints
- Weather information,
- Navigation hazard warnings
- Information to help safety of fishing equipment.
- Analysis synthesizing the above data.

5.1.4. Usecase Walkthrough

The Usecase starts when the fisherman logs on to the service. If successful he is returned with a user interface. He inputs a radius of operation. If without a GPS, he also inputs a place name (nearest). The system retrieves fisherman's position from GPS (or a gazetteer service if GPS is not available). Using the Radius of operation it determines area of interest for which it retrieves framework data i.e. bathymetry, seabed obstructions and navigational aids (lighthouses, buoys). PFZ features, weather information, navigation warnings, marine international boundaries, fisheries restriction areas and other restriction areas are overlaid over the framework dataset after suitable transformations. This map is displayed on the user's interface. The fisherman can click any part of this map to which a route from fisherman's present position is returned. Both the direct route and a best route are displayed. Best route takes into account the sea state, navigational safety, and restriction areas. PFZ forecast must not be more than two days old.

5.1.5. Roles and Actions

The usecase was examined for participating entities and their actions. Table 5.1 below lists the roles and actions identified. Types of objects the roles are associated with is also mentioned.

Table 5.1 Tentative roles and actions - Fisheries Advisory Service

Sl.	Object type	Role	Actions
1	Person	Fisherman	Input initial position Request for Potential Fisheries Zones Request for route to chosen spot.
2	Software system	Fisheries Advisory Service	Determine area of interest Access and display PFZ Access and display navigation safety data, weather data, fishing regulation areas, maritime boundaries Determine route to selected point.
3	Software system	Weather Forecast Agency	Provide weather forecast and warning
4	Software system	Navigation Warnings Agent	Provide Navigation warnings and chart updates.
5	Software system	Fishing Policy Agent	Provide regulatory information on fishing
6	Software system	Fisherman UI	Provide Input Window, Map Display, GPS Position
7	S/W subsystem	Geoportal controller	Fisheries service control Agent
8	S/w subsys	Framework Data System	Provide hydrographic framework data
9	S/w subsys	Weather Information System	Notify weather report and warnings
10	S/w sub sys	Navigation Warning System	Notify Navigation Warnings
11	S/w sub sys	PFZ Information System	Provide PFZ Data Update PFZ Data
12	S/w sub sys	Legal Restriction System	Provide information on Restriction areas, Fishing Regulations, Maritime boundaries

The next issue is to identify enterprise objects. There is a conundrum in distinguishing between roles and objects. We have so far assumed all the participants as roles. To designate objects we check each item in column 2 in table 5.1 above, if it could change states as it goes through the actions in column 3. If it does the item is designated as *object* fulfilling the roles represented by the states. We could also independently identify objects to fulfil either one or more roles in table 5.1 above (column 2) at the current level of abstraction.

To cite an example, the role of fisherman UI (User Interface) has states ShowInputWindow, Show-MapDisplay and GettingGPSposition. Thus Fisherman UI is a candidate enterprise object. Further it also fulfils the role of fisherman.

Similarly the role Fisheries subsystem control agent has states I/O Controller, Access Controller Authentication Agent. So we redesignate Fisheries subsystem control agent as an enterprise object fulfilling the roles I/O controller, Access Controller and Authentication Agent. We have thus refined the enterprise objects and their corresponding roles as listed in table 5.2 below :-

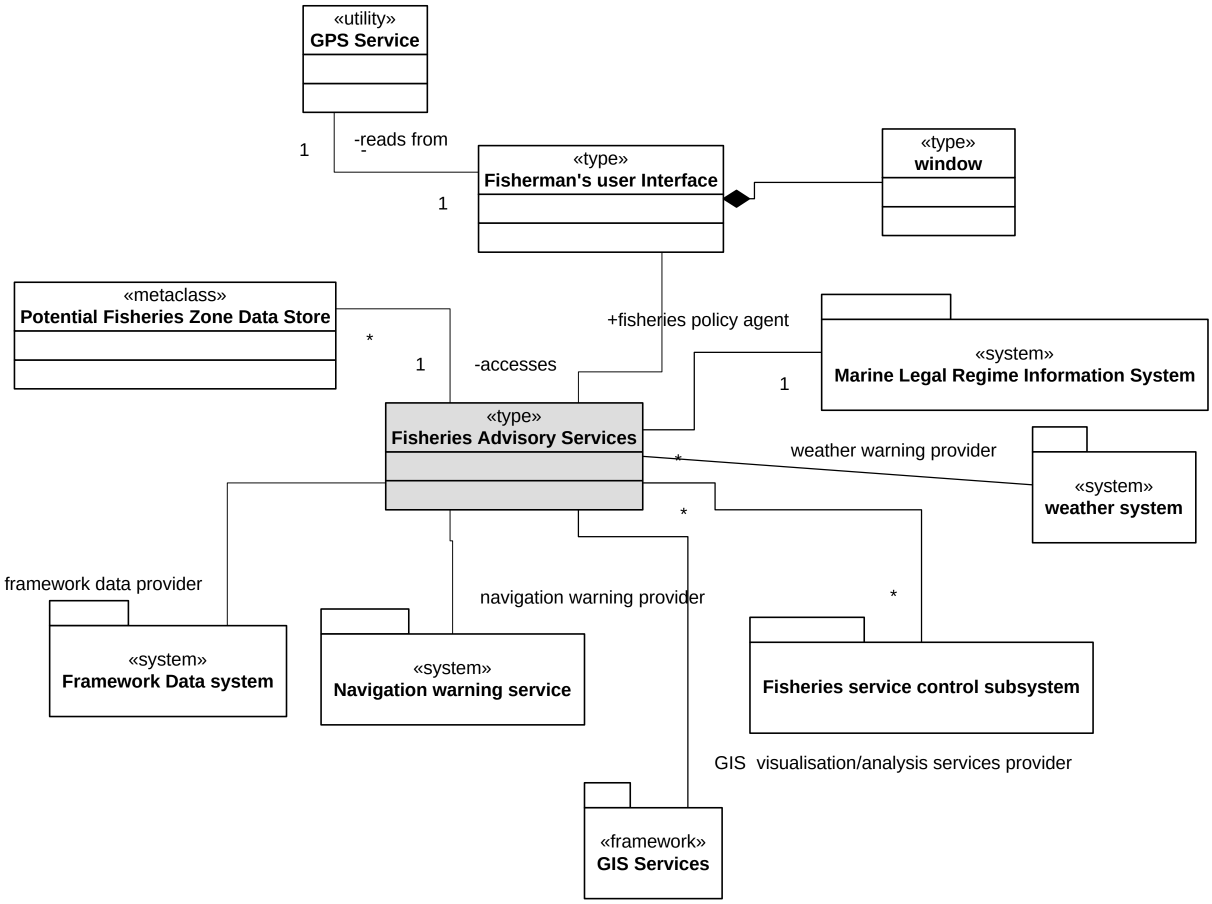
Table 5.2 List of Enterprise objects, roles and constraints

S No	Enterprise Objects	Roles
1	Fisherman User Interface	Input/output window, Map Display, GPS Position Retriever.
2	Fishery Advisory Service	PFZ Data Provider PFZ Data Update Agent
3	Weather Forecast System	Weather/Warnings Notifier
4	Navigation Warning System	Navigation Warnings Notifier
5	Framework Data System	Hydrographic framework data provider
6	Marine Legal Regime Information System	Fisheries Legal Regime Advisor
7	GIS Services	Visualisation /analysis service provider
8	Fisheries service control subsystem	I/O Controller Access Controller Authentication Agent
9	Fisheries regulations repository	Fisheries regulations agent
10	Maritime boundaries data store	Maritime boundaries restrictions agent
11	Fisheries Restriction areas data store	Area restriction Agent
12	PFZ data store	PFZ Data Provider

Further examination of enterprise objects and the actions may yield more objects at a lower level of abstraction. Some of them are MapVisualisationAgent, Coordinate Operations Agent, Route Determination Agent, Map Overlay Agent which are refinement of GIS services object.

We are now in a good position to continue with the enterprise viewpoint with UML class diagrams. The class diagram shows the entities as classes/objects, assigns roles to them, identifies their associations and constraints.

Figure 5.1 Use Case – Fisheries Advisory Service – Class Diagram



5.1.6. Business Processes

Following the methodology defined in chapter 3 , the following actions can be captured between objects from interaction of roles, in our class diagram at figure 5.1 above :-

- Collect Input/Provide Output
- Retrieve PFZ
- Retrieve FW Data
- Overlay PFZ/ Framework Overlay
- Provide PFZ Data
- Provide Framework Data

The Business Process associated with this Usecase has been captured in a UML activity diagram in figure 5.2 below. The swim lanes of the diagram represent enterprise objects responsible for the actions in the process. The enterprise objects are those identified in table 5.2 above. Actions are represented by rounded rectangles. Arrows denote transition from one action state to another. Actions could be internal actions or interactions with other objects.

5.1.7. Preconditions

The following preconditions apply to the business process model:-

- The system has been initialised to enforce area based restrictions, season based restrictions and species based restrictions on the advisory service eg no fishing during spawning season. No fishing near mangroves and in marine protected parks.
- The fishing vessels are medium to large with a GPS, a thin client, internet connection and a suitable fixed device to display maps.
- Fisherman has registered with the Fisherman Advisory Service.
- All databases are adequately populated.

The process model shall be realized as a set of interacting computational objects which will actually execute the actions. This model shall be depicted as chained services model in the Computational view.

5.1.8. Post Conditions

The fisherman has a map with Potential Fisheries Zones displayed on his screen. This is correlated with information on navigational, weather safety and information on marine legal regime affecting fisheries, through framework data.

The process model can be captured in the UML activity diagram as shown below. The columns represents swim lanes in which all actions are the responsibility of objects mentioned the head of the swim lanes. The process model is entered in the top left corner. The fisherman logs on the input is validated by the service subsystem

5.1.9. Community

Next the concept of community is addressed. It is defined in [3] as "a configuration of objects formed to meet an objective. The objective is expressed as a contract which specifies how the objective can be met." To achieve the objectives of Fisheries Advisory Service System, the following communities can be identified :-

Regulatory Community. This has the objective of regulating fisheries. It comprises the Marine legal Regime information System which is composed of marine boundaries data store, Fisheries regulations repository, restriction area data store, .

Safety Community. Its objective is physical safety of the fishing craft. This constitutes the weather service and navigation warning service.

Operations Community. This provides the core Potential Fisheries Zone data with the underlaying framework data processing services. One possible set of communities is captured in UML package diagrams in figure 5.3 below. Modelling communities help guide distribution aspects of the distributed system by grouping resources.

5.1.10.Geoservices Design Methodology (GSDM)

It is useful to draw comparisons with the 'external perspective model' of Geoservices Design Methodology (GSDM) [23] , which describes a Geoservice Information System's external behaviour by identifying "the boundary interactions from the user's standpoint". The system is considered a black box. The difference with the RM-ODP enterprise viewpoint is seen in that in addition to external entities, RM-ODP also considers the internal (enterprise) entities of the system. Figure 5.4 below captures a simplified version of external perspective of GSDM modified as explained above.

Figure 5.2 Fisheries Advisory Service Usecase - Business Process - UML Activity Diagram

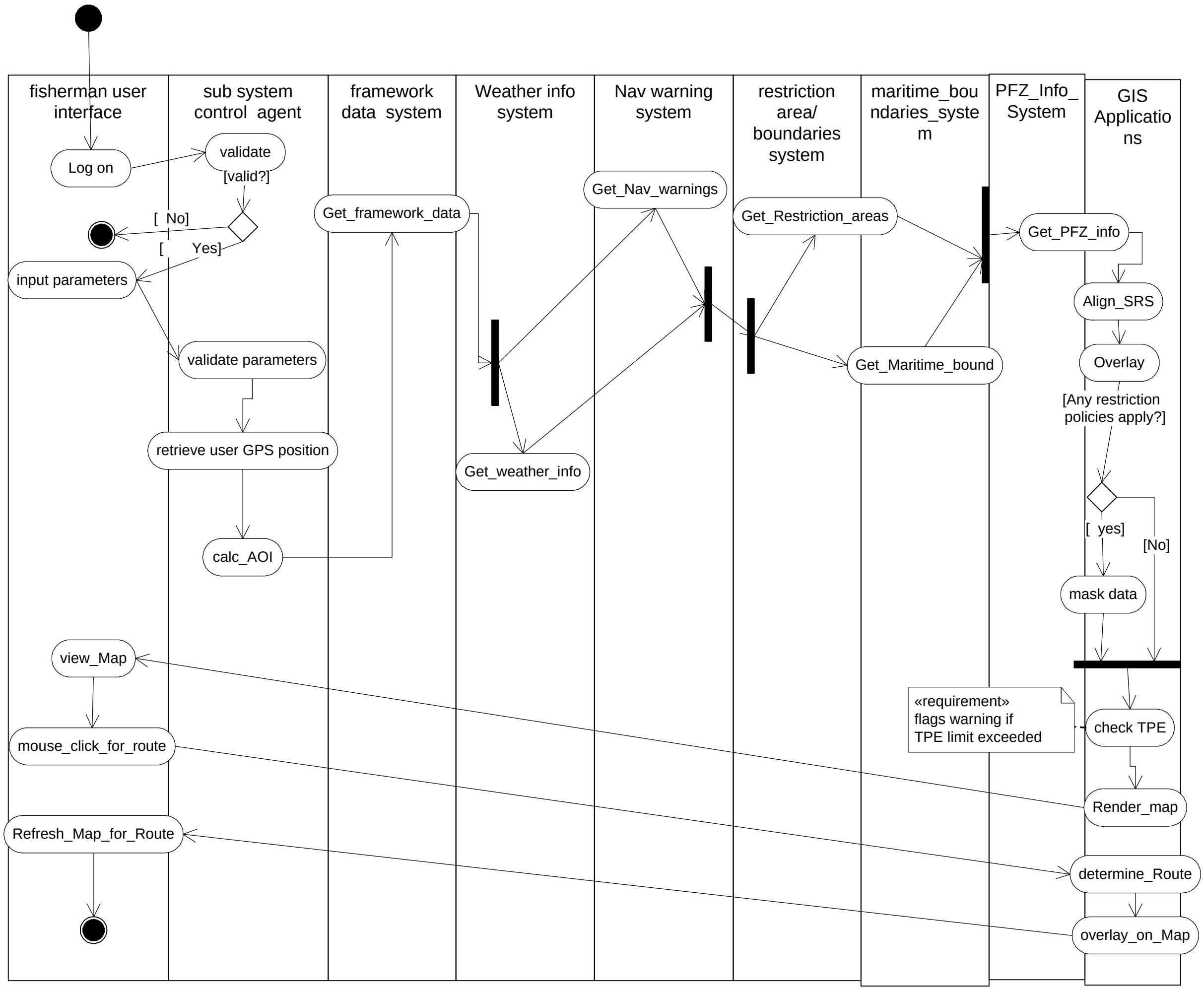


Figure 5.3 Fisheries Advisory Service – Fisheries Community – UML Package Diagram

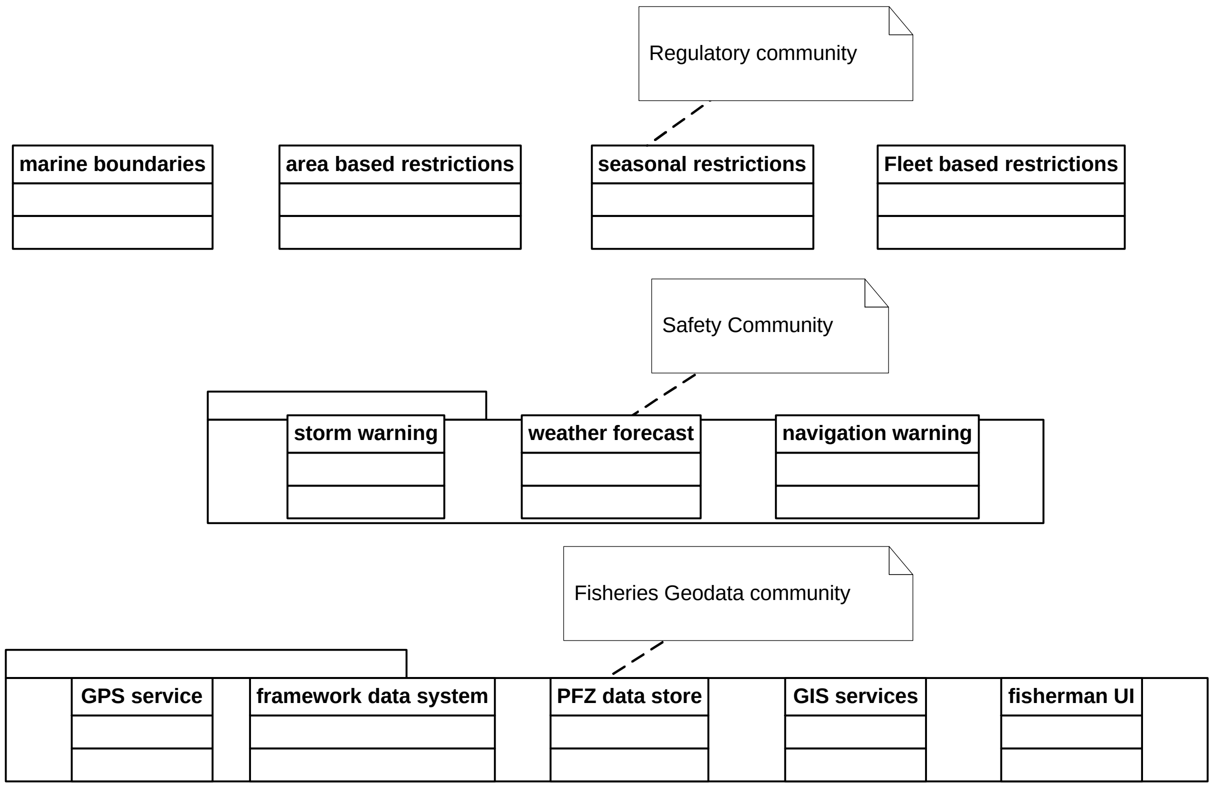
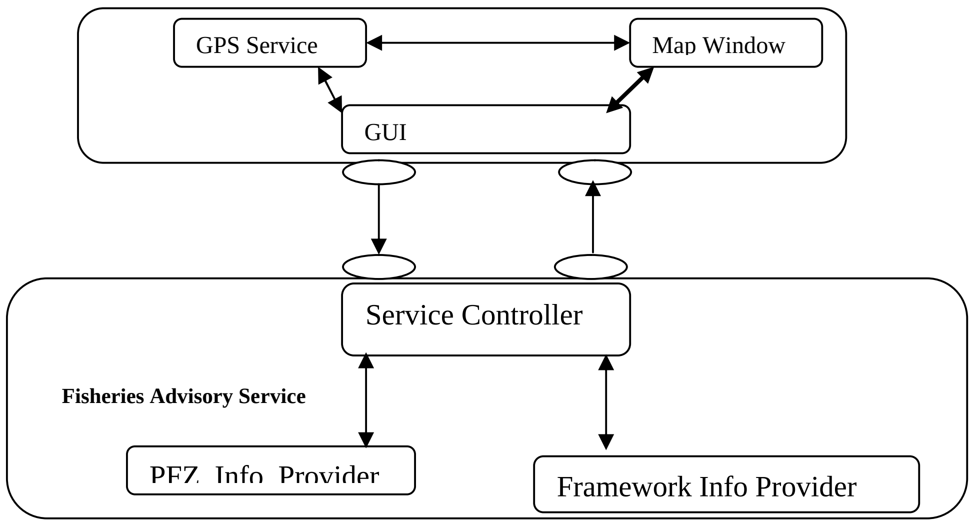


Figure 5.4 A perspective of Fisheries Advisory Services from Geoservices Design methodology [22]



We have two main top-level entities in the model above – the Fisherman's User System and the Fisheries Advisory Service. Each of these entities have been decomposed showing their interrelationships. It is seen that that this perspective gives an intuitive picture of the architecture in terms of composition and decomposition and is considered to supplement the corresponding constructs of UML in terms of Class and package diagrams.

5.1.11. Policies

The next major element defining the enterprise specifications is policy. It's RM-ODP definition is "a set of rules related to a particular purpose. A rule can be expressed as an obligation, a permission or a prohibition" [3]. A list of policies identified for the Usecase have been listed below categorized under entities as applicable i.e. community, business processes, objects, or roles.

5.1.11.1. Related to Community

The Geoportal must primarily adopt Open GIS standards particularly OGC Web Services to develop the architecture.

Framework data is to be provided only by authorized government agencies based on consensus standard content models for several basic themes with specifications including quality as needed to ensure interoperability.

Only a nominal fee to cover 50% of the maintenance costs of the system is to be charged from the user.

5.1.11.2. Related to Business Process

- All vessels are obliged to be registered with the Fishing Advisory service. The latter is obliged to record full details and capabilities of the craft.
- Vessels more than 20 metres length shall not be provided with PFZ data and seabed obstruction data in water less than 30 metres.
- No PFZ data shall be provided during the spawning season of fish eg the monsoons.
- All legislation and regulations governing fisheries conservation apply. such as marine parks, prohibitions/regulations, size of devices , methods etc.
- Fishing is prohibited in Exclusive Economic Zones of foreign countries.
- It is permitted in the high seas subject to bilateral or multilateral agreements as per United Nations Convention on the Laws of the Sea. [8]

5.1.11.3. Related to Enterprise Objects

- The PFZ data used should not be more than 2 days old.
- PFZ data should always be sourced from Department of Space.
- PFZs lying in areas prohibited for fishing shall not be displayed.
- PFZ lying on the other side of international marine boundaries are prohibited from being displayed.
- PFZ lying in the high seas are permitted to be displayed.
- The source of framework data and navigational warnings must be National Hydrographic Charting authority.
- The source of fisheries restrictions areas and conservation regulations should be the Department of Fisheries (Ministry of Agriculture).
- Source of the marine boundary data should be the Ministry of Foreign Affairs.
- Data shall be held and maintained by the service provider
- The data provider must be responsible for the quality of the data

- Data provided must conform to the security guidelines of the Ministry of Defence eg
- No oceanographic data is to be provided on a grid closer than 30 nautical miles.
- All legacy data available with various data providers should be accessible in the system without any data conversion.
- Data provided should be on WGS Datum with Indian Mean Sea Level as the vertical Datum.

5.1.12. Environment Contract

5.1.12.1. Environment Contract With Local Administration

Obliged to notify details of new fishing craft registered.

5.1.12.2. Environment Contract With Central Govt

- Notifies area-based, fleet based and season-based restrictions.
- Reviews them and intimates revisions.
- Ensures that all relevant data is provided freely on the internet subject to ecological and security restrictions.

5.1.13. Quality of Service

- GIS Services shall provide overlay functions to an accuracy of +/- 1 metre.
- The positioning accuracy of framework data from framework services should be better than +/- 3 metres.
- The inter-se priority to services shall be weather warnings, navigation warnings, routine weather reports, area based restriction information.
- PFZ data should be not more than 2 days old.

5.2. Fisheries Advisory Service Usecase - Computational View

5.2.1. Services Identification

Following the methodology in chapter 3 , first all tasks requiring automation are listed as in Table 5.3 below:-

Table 5.3 List of Tasks and Services

Sl.	Tasks	Required Service	Source
1	Discover Fishery Advisory Service	Catalogue service	OGC discovery application service [1]
2	Provide User Interface to Fisherman's System	Geographic viewer service	OGC Client service[1]
3	Receive User Input	Geographic viewer service	OGC Client [1]
4	Retrieve user's GPS Position	Sensor Web Application Svc	OGC OSF [1]
5	Retrieve Hydrographic framework information features	Coverage Access Service (CAS) Feature Access Service (FAS) (FAS adopted as OGC WFS implementation specifications)	OSF [1]
6	Retrieve PFZ(Potential Fisheries Zone) objects	FAS	OSF [1]
7	Retrieve Restriction objects (Boundaries/Areas)	CAS	OSF [1]

[8] www.un.org

Sl.	Tasks	Required Service	Source
8	Retrieve weather objects	CAS and Coverage portrayal Service and WFS	OSF [1]
9	Retrieve Navigation warning objects	FAS (OGC WFS)	OSF [1]
10	Transform Coordinates	Coordinate transformation and conversion services	OSF [1]
11	Determine Route	Route Determination Service	OSF [1]
12	Overlay Features/ Coverages	Feature Manipulation Service	ISO 19119 [7]
13	Portray Map	Coverage Portrayal Svc (implemented as OGC WMS+ SLD[9])	OSF [1]
14	View Map (by user)	Map Viewer Service	OSF [1]

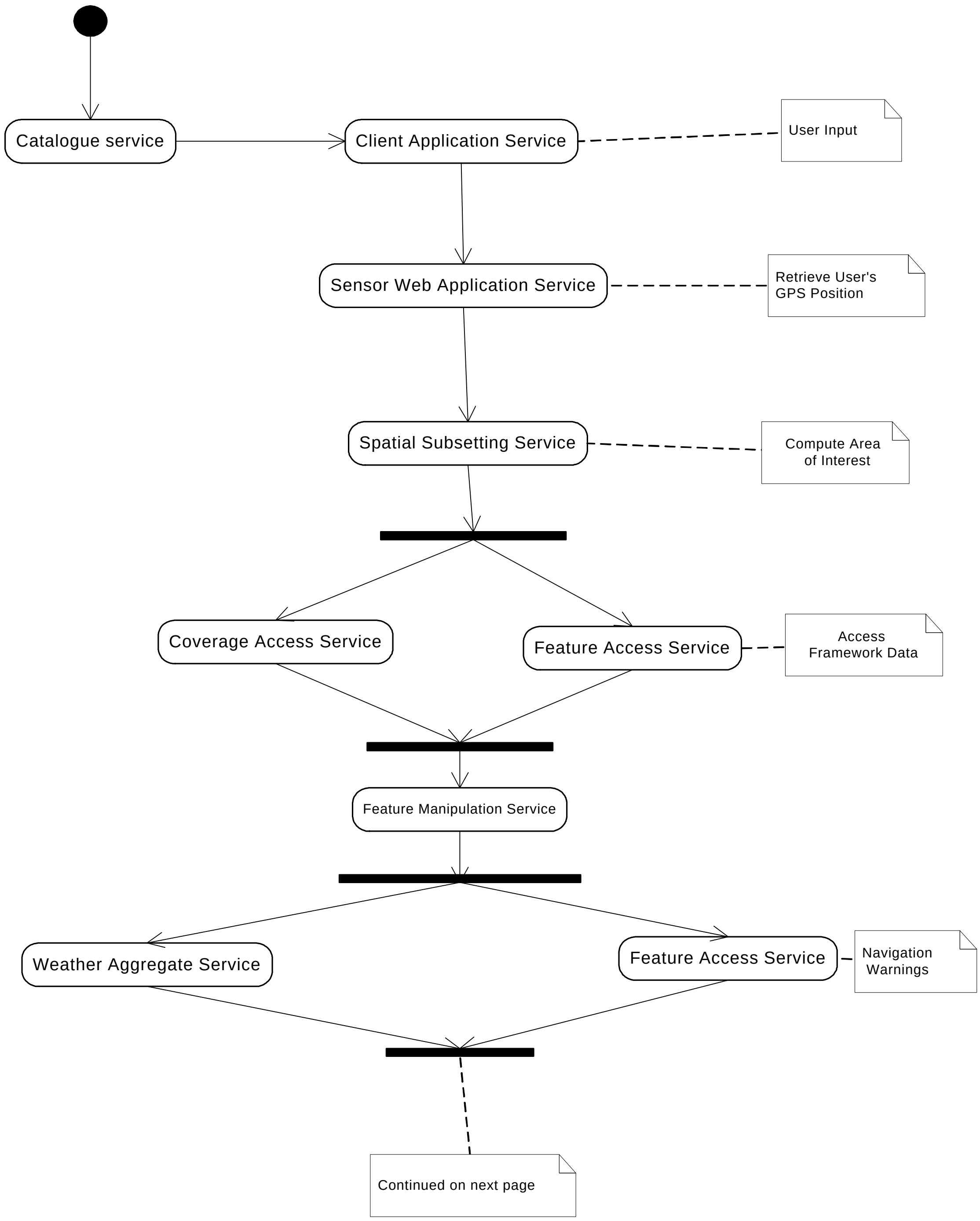
In the next step the required service components to carry out the tasks have been identified. These are also listed in table 5. 3.

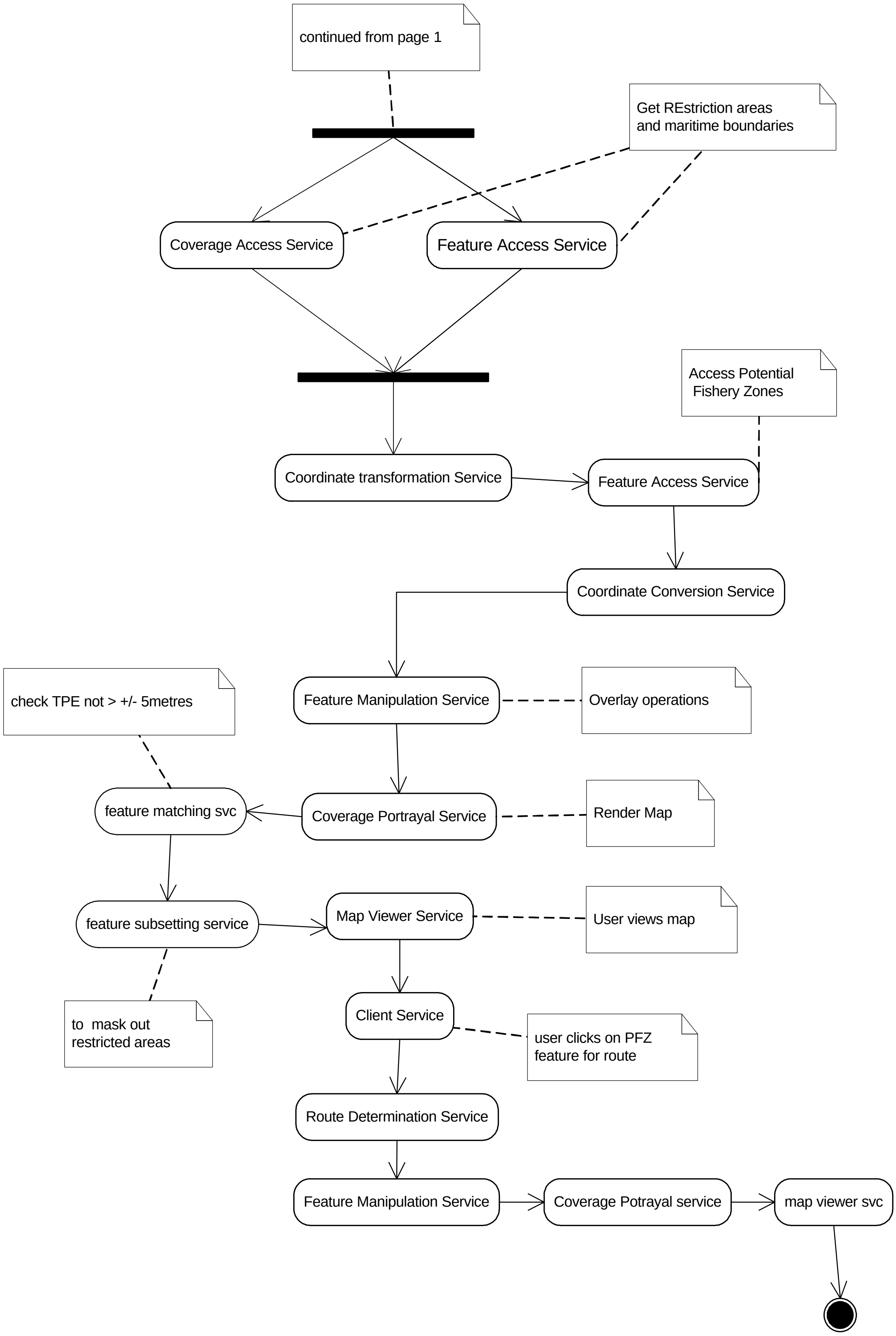
5.2.2. Service Chain

It may be seen that any one service on its own cannot fulfil the tasks or realize the business process. It is necessary to link them in service chains. For a service chain input of one service depends upon another service. Thus they are modelled as a Directed Acyclic Graph (DAG). The UML activity diagram in figure 5.5 below models a suggested chain to realise the business process in figure 5.2. The [5]. The figure is self explanatory. At the bottom of page 2 of the DAG , a feature matching service is employed to compute Total Propagated Error to check if it exceeds the quality standard specified. If it does , a message is generated. The message has not been modelled to reduce complexity. Further , after the PFZ data is delivered to the fisherman, he has the option to click on a selected PFZ feature (or any point). This returns a route.

[9] Styled Layer Descriptor Language

Figure 5.5 Activity Diagram – Service Chain Directed Graph




continued from page 1
Get REstriction areas and maritime boundaries
Coverage Access Service
Feature Access Service
Access Potential Fishery Zones
Coordinate transformation Service
Feature Access Service
Coordinate Conversion Service
check TPE not > +/- 5metres
Feature Manipulation Service
Overlay operations
feature matching svc
Coverage Portrayal Service
Render Map
feature subsetting service
Map Viewer Service
User views map
to mask out restricted areas
Client Service
user clicks on PFZ feature for route
Route Determination Service
Feature Manipulation Service
Coverage Potrayal service
map viewer svc

5.2.3. Architecture Pattern of Service Chain

An architectural pattern expresses a fundamental structural organization or schema for software services [7]. In terms of the template used in [7], the architecture pattern of this service chain can be defined as below.

5.2.3.1. Name

The service-chain primarily provides advisories on Potential Fisheries Zones and routes to them. So the appropriate nomenclature is Potential Fisheries Zone Advisory Service (PFZ Service).

5.2.3.2. Problem

All fishing vessels need to be provided with a picture of PFZ integrated with safety and legal regimes. This needs to be done in an environment and through communications bandwidth which is not conducive for constant two way communication.

Context: It is possible to provide the above mentioned information based on ocean observation systems, navigation services, weather services and services providing information on conservation and boundary matters. However, the user does not need to know of the constituent services. It suffices that he knows of the PFZ Advisory Service and its source. The constituent services need to be initially populated and constantly updated thereafter.

5.2.3.3. Forces

This chain has been modelled as an aggregate service. The considerations behind this are as follows:-
All data i.e. PFZ features, framework data, maritime boundaries data are assured to come from authorized state sources.
The semantic validity of the chain needs to be established by the service provider.
The user environment is not conducive to any other form of chaining. It is found in the chain that services are being invoked for four different types of data separately which is beyond the scope of user control chaining and no particular benefits are seen in workflow control chaining as the resultant stream of errors is expected swam the user.
The service sequences involved with the different types of data could first be tested for robustness and quality before being deployed as aggregate services. Similar patterns are likely to be discovered in other use cases. The main data types from authorized sources are as follows :-

- Marine framework data depicted on chart like wrecks, bathymetry, bottom obstruction, coastline, lighthouse.
- Thematic data of primary interest eg Potential fisheries Zones, Mean Depth.
- Legal regime of international, administrative boundaries.
- Weather constraints like sea state, wind etc.

5.2.3.4. Structure

The architecture pattern of the chain is modelled as UML collaboration diagrams at figure 5.7

5.2.4. Description of the Service Chain

Service Invocations in the UML collaboration diagram in figure 5.6 are denoted in brackets thus () in this description. The diagram in figure 5.6 shows how the required services are structured and collaborate to realise the business process in enterprise view at figure 5.2. The chain is a composite chain of implied chains, workflow controlled chains and aggregate chains. The aggregate chains are particularly based on the concept of composition/decomposition.

(1) The fisherman establishes the URL of the Fisheries Advisory Service through a catalogue service and invokes the fisheries aggregate service . This runs a client application service and returns a user Interface to the fisherman. The user logs on. The client svc validates and initiates the Workflow Controlled, Fisheries Advisory Service.

(2) The chain asks for user's position and desired radius of operation which a sensor web application service provides. This receives data from user's GPS. If no GPS is available a locality name may be entered in which case a gazetteer service will be invoked to return the geographical position (the latter scenario has however not been modeled as place names at sea refer to large geographical areas and will not always serve the purpose in our usecase). In the same call to a sub-setting service is nested to get an area of interest. It would also decide whether the area is covered by the service.

(3) This is an invocation to framework service to retrieve framework data for the Area of a Interest (AOI). The data is returned directly to the workflow enactment service.

(4) and (5) is a nested workflow chain which provides the safety information. The objects involved here roughly correspond to the safety community in section in 5.1.9. This invocation is to a weather aggregate service, followed by navigation safety aggregate service. Both will be constituted of chains of Coverage Access Service (CAS) and Feature Access Service (FAS).

This is followed by an invocation (6) to the aggregate service providing data on the Policy regime , also comprising CAS and FAS. This service is a composite computational object that corresponds to the Regulatory community in Enterprise View in section 5.1.9. It provides restriction areas, season based restrictions, fleet based restrictions, maritime boundaries and all other constraints to disseminating PFZ data.

The Policy aggregate service is chained to a Feature Access service providing the PFZ (Potential Fisheries Zone) service. Next the PFZ service is invoked (7) with a nested call to an aggregate data fusion and filtering service . The PFZ service accesses the resultant data from the Policy regime service, (7.1) and invokes an aggregate service (7.2) which fuses all safety, regulatory and PFZ data and filters the PFZ data through the policy parameters accounting for area based, fleet based or season based restrictions, quality of data etc. The policies are defined in section 5.1.11 in the enterprise view. Another correspondence to the enterprise viewpoint is visible here.

In (7.4) the PFZ service responsible for the main data of interest ie PFZ returns all data retrieved in the chain integrated and filtered ready for rendering to the use. The PFZ service together with the fusion/filter aggregate service corresponds to the Fisheries data Community.

The integrated data is portrayed by a Coverage Portrayal Service (CPS) (9). (OGC has implemented such a service, as Web Map Service (WMS) implementation specification enhanced with a Styled Layer Descriptor (SLD) language). A map viewer service is invoked at (10) to provides the tools for map viewing at the user end. This is enabled through the UI provided by the client application service.

The user sees the map and clicks at some PFZ for route (12). The Workflow service invokes at (13) a route determination service. By linking to web sensor service to get the latest position and the available adata on weather and other constraints a route is determined and passed on to the client application service for display on user's system.

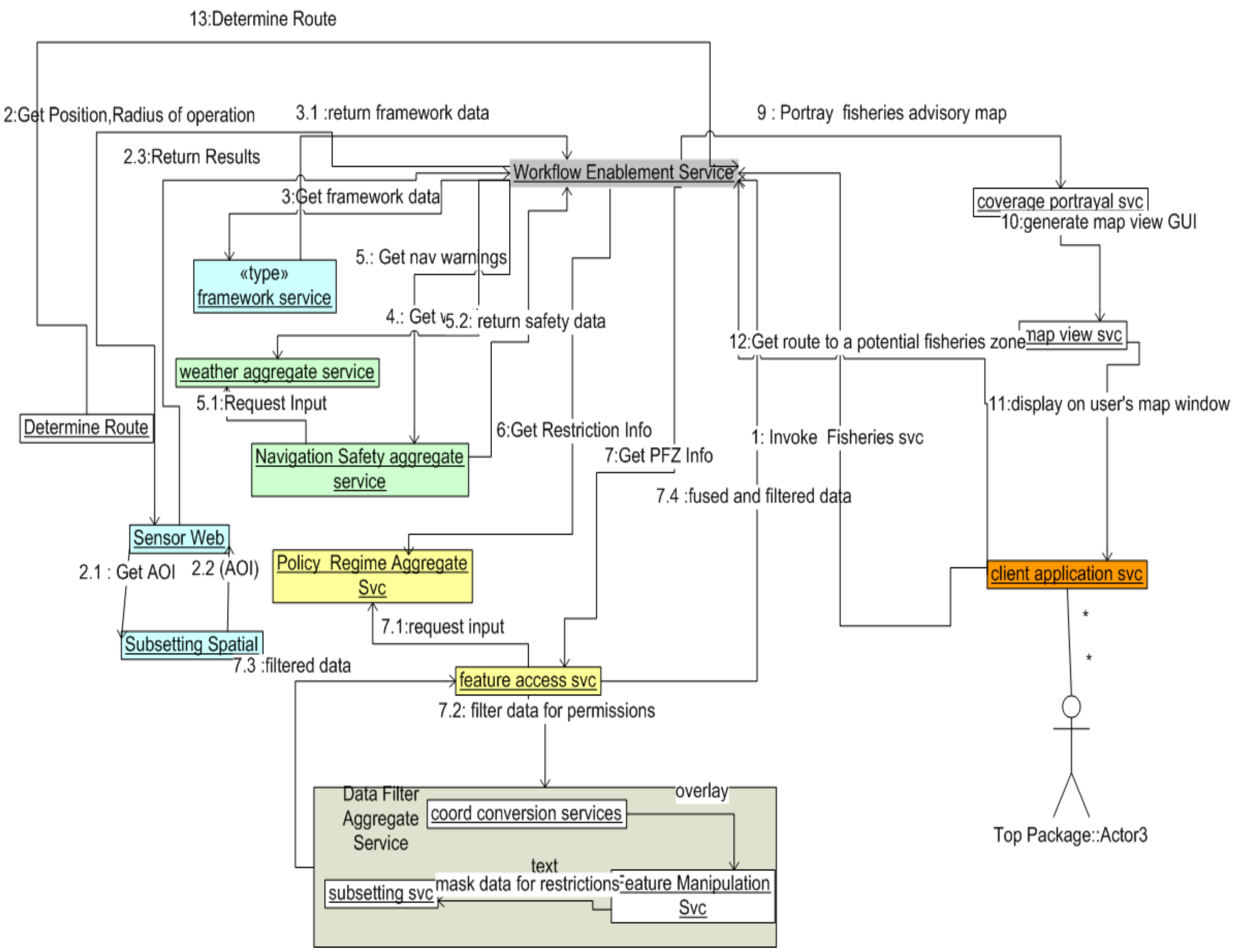
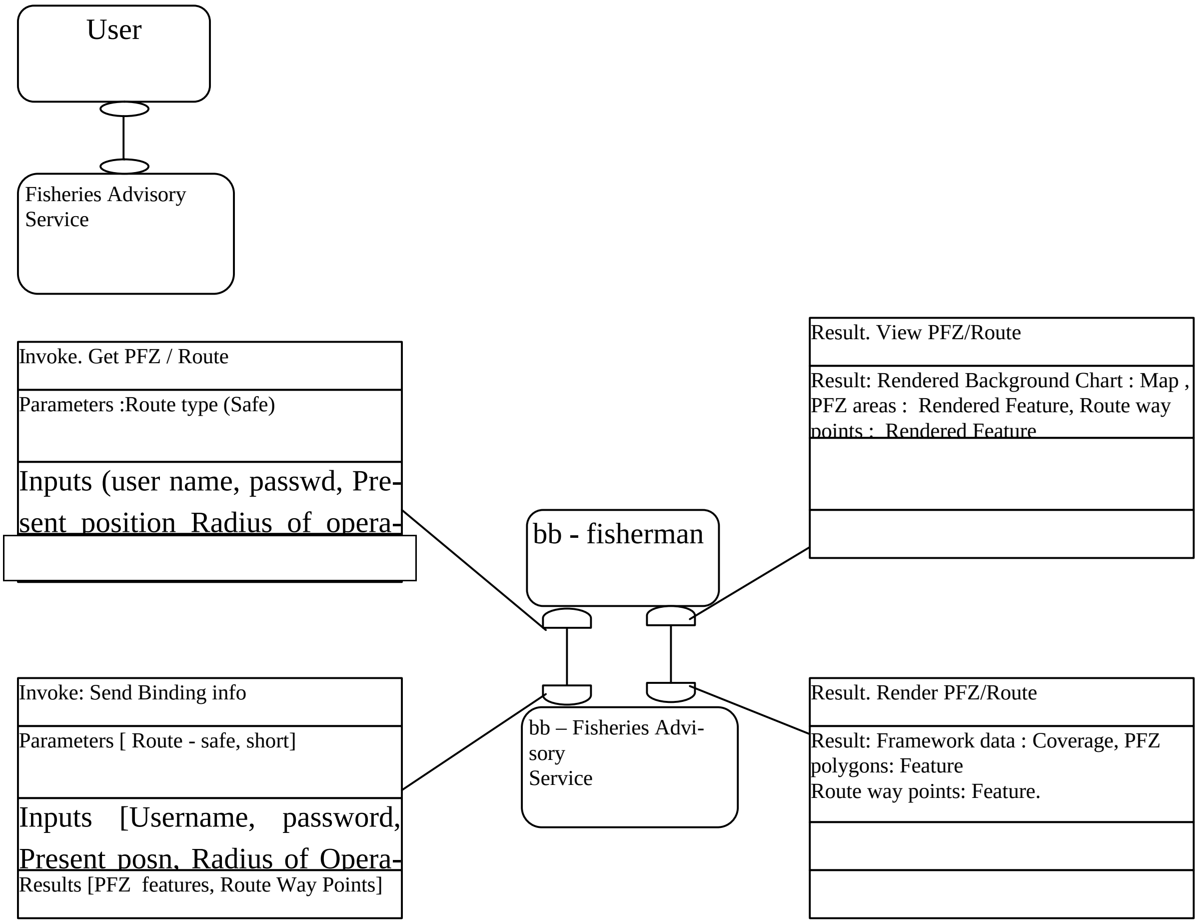


Figure 5.6 Collaboration diagram Fisheries Advisory Service

The interactions between these computational objects have been captured in a sequence diagram which is placed at Appendix B.

The concept of GSDM [22] is once again employed to model the interactions between the user interface and the service interface. Though it is not examined in detail the author perceives that GSDM could be interwoven into the RM-ODP based methodology to reinforce the latter.

Figure 5.7 Interactions at Enterprise Object Level after Geo Services Design Methodology (Morales (2004).



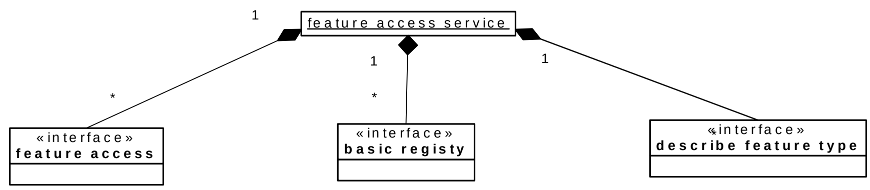
5.2.4.1. Service Capability Information

The figure 5.8 above also depicts the information flow at the interface of the PFZ Advisory Service as seen by the fisherman user interface. The bottom left rectangle, connected to the Fisheries Advisory Service, also models the Service Capability , information which is returned by the operation Get Capability, based on which service chaining will be carried out either by human user or workflow enablement services.

5.2.4.2. Interfaces

Figure 5.8 A Service component with its interfaces.

In the figure 5.9 is depicted the interfaces of a service used in this architecture. The interfaces are shown as class diagrams.



5.3. Information Viewpoint

In accordance with the methodology indicated in chapter 3, each step in the business process at figure 5.2 is examined to identify information objects of four types - Inputs (type and value) , Outputs (type and value), Resources (instance info or state), System Control info. These are shown in the table 5.4 below . Before that an over view is provided in figure 5.11 below, which captures the information objects in the PFZ Advisory Process from the Perspective of Inputs, Outputs, Controls and Resources [1].

Figure 5.9 Fisheries Advisory Services – representative block diagram of inputs, outputs, control and

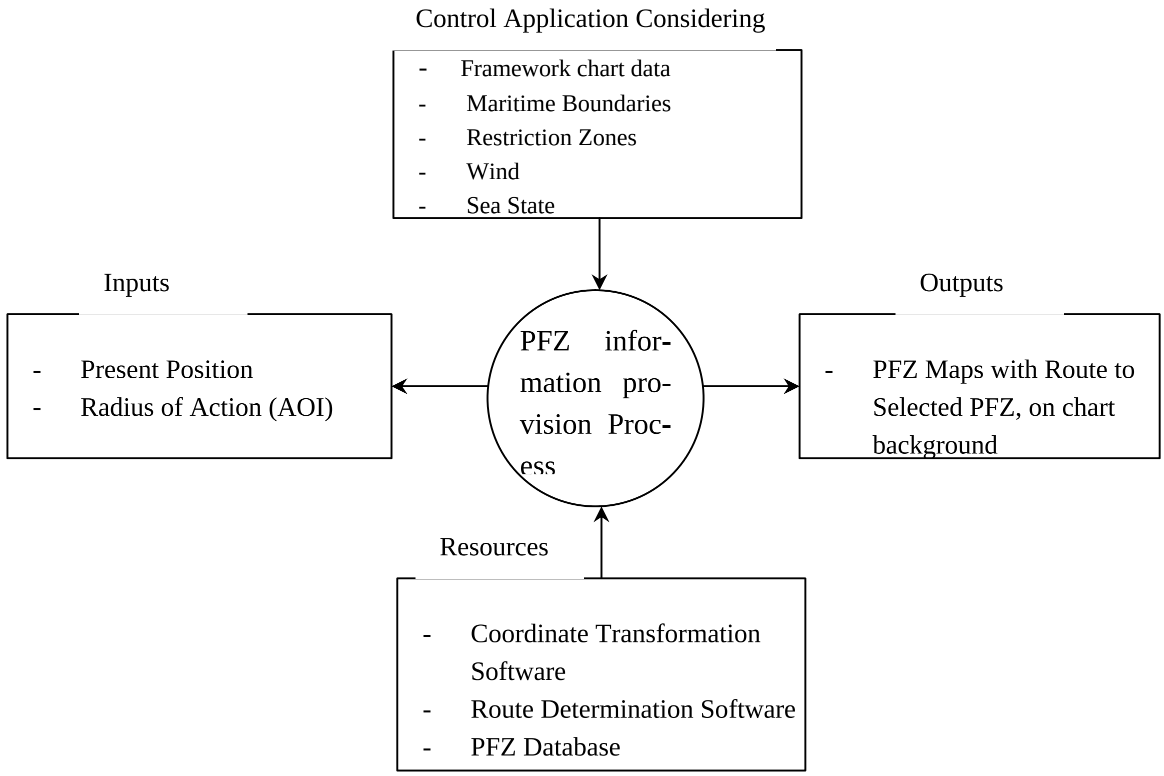
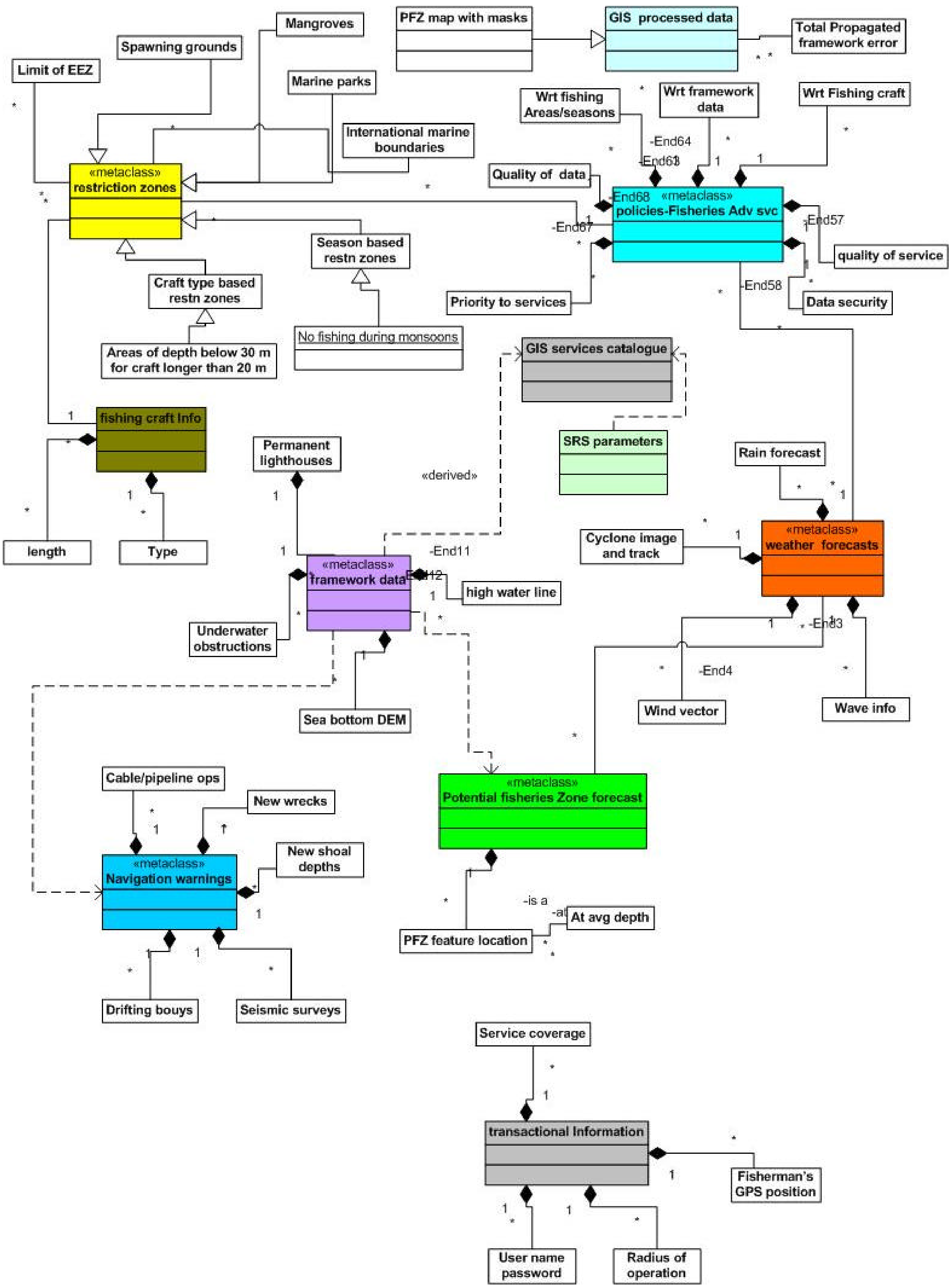


Table 5.4 Fisheries Advisory Service – List of information objects

The data structure of this information is captured in the class diagram in figure 5.11 below. The communities described in enterprise view are also reflected in the class diagram in the natural clusters of classes which may be seen.

Figure 5.10 Class Diagram – Information Objects



5.3.1. Invariant Schema

The invariant schema constitutes the following conditions which must always remain true.

- International maritime boundaries, Fisheries restriction zones, Fisheries management policy
- The user must be previously registered with the Fisheries Advisory Service.
- The framework data should either be sourced from or authenticated by the National Hydrographic Agency.
- All data fusion shall be done on the WGS 84 datum.
- The vertical datum for all heights on land shall be Indian Mean Sea Level.
- All depths shall be referred to the local chart datum as shown on the largest scale chart of the National Hydrographic Agency.
- PFZ Information
- No PFZ advisories shall be provided during fishing spawning seasons (eg the monsoons).
- No PFZ information shall be provided in areas prohibited for fishing seasonally.
- No PFZ information is permissible in designated areas such as marine parks. Details are in information element Fishing Regulation Policy.

5.3.2. Dynamic Schema

As mentioned in chapter 3, it is the specification of the state changes permitted for one or more information objects, subject to constraints of any invariant schemata. This has been captured for the high level information objects, Fisherman User Interface and PFZ Information System, in a state chart diagram in figure 5.12 below. It has been shown how the dynamic schema is subject to the invariant schema.

5.3.3. Static Schema

Some states of two of the enterprise objects depicted in the Activity diagram in figure 5.2 are given in the following diagram which is a modification of the state chart diagram. All the states are subject to the invariant schema. This constraint has been partially captured in the diagram. The broken arrows from left to right from states of one object to another represent that states of the fisherman UI object overlap in time with the corresponding state of the PFZ Info system object.

Figure 5.11 UML State Chart Diagram depicting Dynamic Schema(Fisherman UI & PFZ Info System)

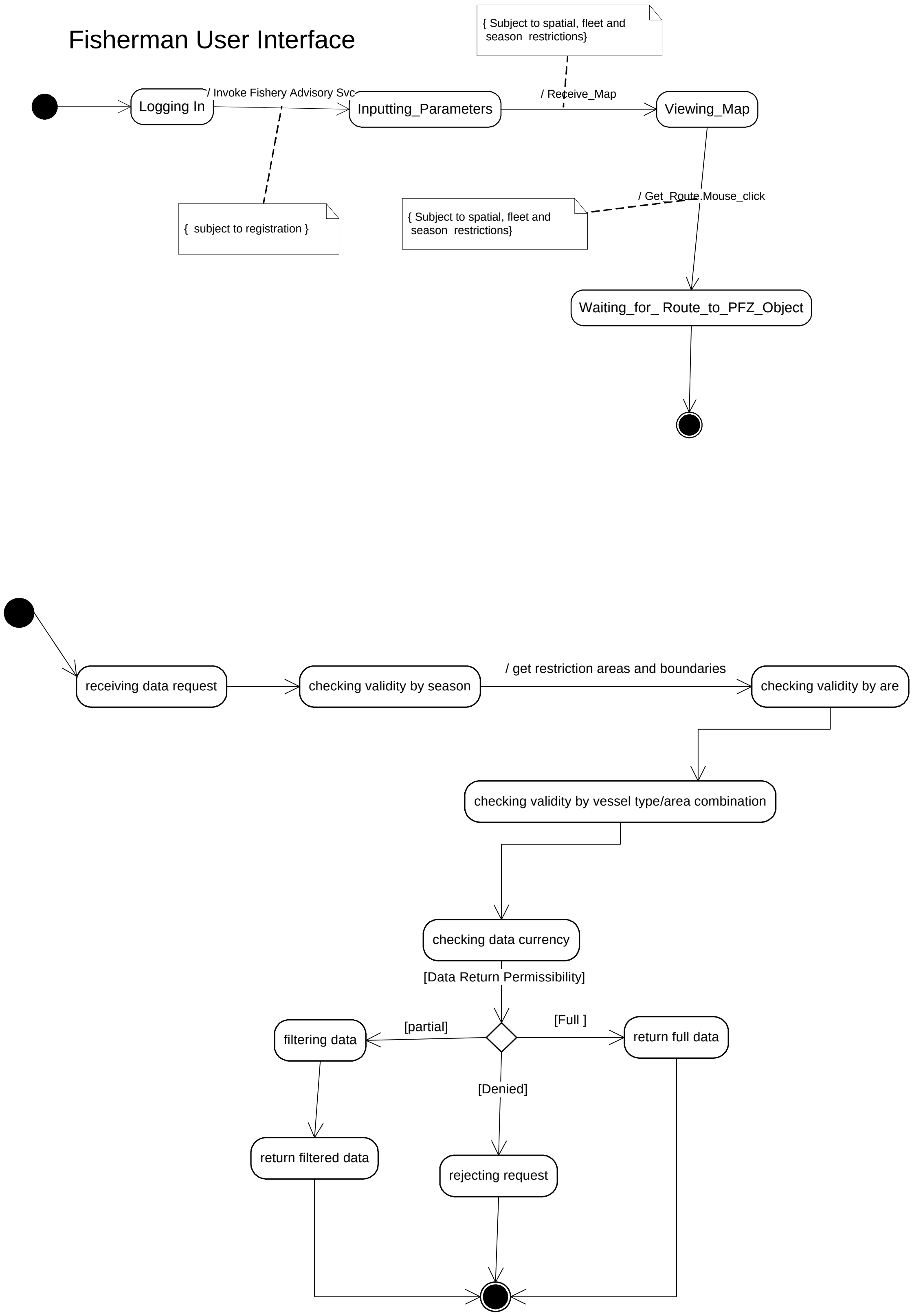
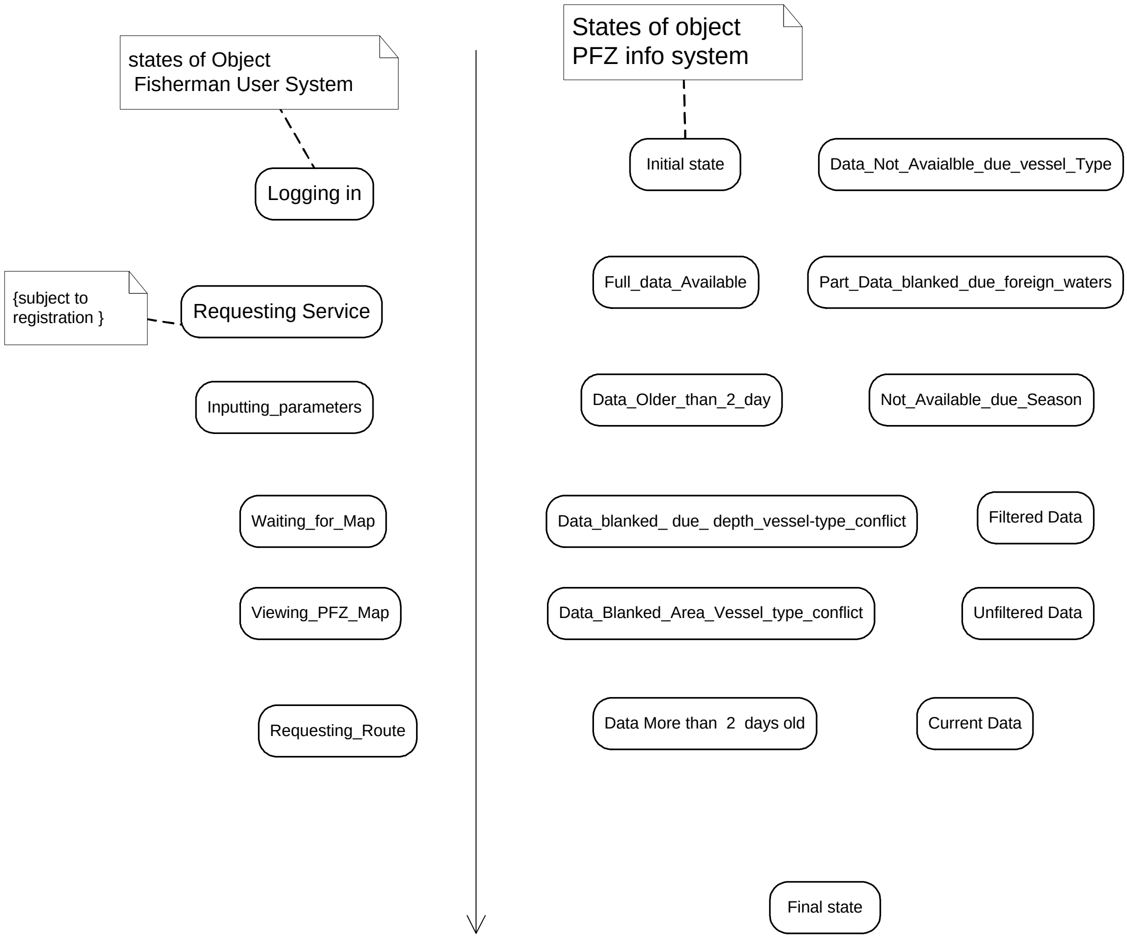


Figure 5.12 PFZ Advisory Svc – Static Schema (Fisherman UI & PFZ Information System)



Feature Catalogue

The Marine Geopotal will need to develop a feature catalogue commonly understood by all stake-holders. Some suggestions for compiling standard sets of features necessary for this Usecase are given below :-

- Framework Data - International Hydrographic Organisation standard S 57 version 3.1 for Electronic Navigation Chart

- Coastal Management Features – US Digital Navigation Chart (DNC) feature catalogue. DNC is the US Navy standard of Electronic Navigation Chart and caters for coastal features being more military oriented.

- Maritime Boundaries – under standardization – May be adopted based on the simple feature model of ISO/OGC.

- Weather features – World Meteorological Organisation Standards

- Navigational Warnings. Marine Information Objects, that is afloat navigation hazards have been standardized by IEC for marine radar and navigation systems. The same standards could be adapted.

5.3.4. List of Data Identified as Framework

Based on the criteria of their ability to integrate land and marine domains, to integrate marine data from different sub domains, the following datasets have been suggested for adoption as framework data :-

- Bathymetric Grid
- Bathymetric DEM
- Coastline (High water Line)
- Low Water Line
- Permanent underwater obstructions
- Lighthouses
- Coastal Benchmarks
- Coastal Geodetic Stations
- Shipping routes
- Harbour channels
- Restricted Areas (Anchoring, Fishing, Dumping, Marine parks)
- Territorial waters Limit
- Contiguous Zone Limit
- Limit of Exclusive Economic Zone
- Outer Edge of Continental Shelf

- Nature of Sea bottom (Grid)
- Magnetic Variation charts
- Sea Gravity Charts

5.4. Concluding Remarks

It could be seen in this chapter how business processes can be realized as chained Services to satisfy User Requirements. Correspondences were found throughout from enterprise viewpoint to computational and informational viewpoint, via the common conceptual framework of RM-ODP. The issue of testing the architecture is addressed in the next chapter.

6. Testing the Fisheries Usecase for Consistency

The fisheries Usecase has been specified for RM-ODP Enterprise, Computational and Information viewpoints making up a Reference Architecture for this Usecase. The issue of testing this architecture is treated in this chapter. RM-ODP provides two concepts of testing - Conformance and Consistency.

6.1. Conformance (to ODP standards)

Conformance relates an implementation to a standard. Any proposition that is true in the specification must be true in its implementation. A conformance statement is a statement that identifies conformance points of a specification and the behaviour which must be satisfied at these points. Conformance statements will only occur in standards which are intended to constrain some feature of a real implementation, so that there exists, in principle, the possibility of testing [3]. This however is a test of how an implementation conforms to the architectural specification. This aspect is beyond the scope of this study .

6.2. Consistency

Consistency stands for mutual consistency between one or more viewpoint specifications comprising a system specification. The mutual consistency of the concepts of RM-ODP is inherent to the standard. But whether they have been applied as intended needs to be tested. This is testing for consistency. Consistency provides an assessment of the architecture in terms of completeness and reliability. Testing the internal consistency of the architecture also provides “the ability to check conformance to the requirements” [5]. It is treated here within the scope of the Reference Architecture which is limited to Enterprise, Information and Computational Viewpoints, with reference to consistency rules provided in RM-ODP part 3, [3].

6.3. Consistency Rules – Excerpts from RM-ODP

A summary of the Consistency rules specified in RM-ODP part 3 [3] have been reproduced in this section for subsequent use in the testing.

The correspondences are expressed as interpretation relationships linking terms in one viewpoint language to terms in the other viewpoint language. The key to consistency is the idea of correspondences between specifications, i.e., a statement that some terms or structures in one specification correspond to other terms and specifications in a second specification.

This Reference Model does not declare generic correspondences between every pair of viewpoint languages. RMODP part 3, defines specification of correspondences between a computational specification and an information specification, and between a computational specification and an engineering specification.

A complete specification of a system includes statements of correspondences between terms and language constructs relating one viewpoint specifications to another viewpoint specification, showing that the consistency requirement is met.

Objects identified in one viewpoint can be specified using the viewpoint language associated with that viewpoint or using the viewpoint languages associated with other viewpoints. It is however not necessary to specify an object fully from every viewpoint in order to achieve a mutually consistent set of viewpoint specifications.

A set of specifications based on this Reference Model will, in general, need to relate all the viewpoint specifications

6.3.1. Computational and information specification correspondence Rules

This Reference Model does not prescribe exact correspondences between information objects and computational objects. In particular, not all states of a computational specification need correspond to states of an information specification. But two rules have been specified in para 3 [3] :-

1. Where an information object corresponds to a set of computational objects , static and invariant schemata of information object correspond to possible states of the computational objects.

2. Every change in the state of the information object corresponds either to some set of interactions between computational objects or to an internal action of a computational object. The invariant and dynamic schemata of the information object correspond to the behavior and environment contract of the computational objects.

6.4. Demonstration of Consistency

The object PFZ Information depicted in the Information Viewpoint originates from the enterprise object PFZ Info System in the activity diagram of Enterprise view in figure 5.2 . It is taken up as a test case. The object PFZ Information corresponds to the following three computation objects in the collaboration diagram in figure 5.6 :-

- Feature Access Service invoked at (7) for PFZ data.

- Policy Regime Aggregate svc invoked at (6). It gets both restriction areas and maritime boundaries and other constraints.

- The Data Filter Aggregate Service which is invoked at (7.2) by FAS provifing coastal does data fusion on the data travelling in the chain and thn masks the data according to the dissemination policy.

The consistency rule in section 6.3.1(1) above, under test, requires that for correspondence between, the Information object PFZ Information and the abovementioned three computational objects, there should be a correspondence between the relevant static, dynamic and invariant schema in the Information specification on one hand , and the possible states and interactions of the computational objects on the other. This is examined below.

The correspondence between the invariant and static schemata on one hand and possible states of the computational states on another are explained employing the diagram in figure 6.1 which reproduces relevant extract of the invariant schema on top left, the static schema (for the Information Object PFZ Information), on top right. At the bottom of the diagram is an extract of the collaboration diagram at figure 5.6 showing the corresponding computation objects in the service chain from the computational view. The dynamic schema of PFZ information object is also depicted in figure. 6.2 below .

The correspondences have been shown by colouring the objects in the same colour across different parts of the diagram as applicable.

Four correspondences have been highlighted in the figure. The information object *PFZ information* corresponds to at least three computational objects in the computational viewpoint, namely the service components providing PFZ information, area restrictions and maritime boundaries. It may be seen from the diagram how the possible states of these computational elements as shown in the diagram correspond to the static schema of the information object PFZ information and the relevant classes of the invariant schema i.e. *Restrictions by vessel type/area combinations*, *prohibited areas, General Regulations and Quality of service.*

For example, on receiving requests for PFZ data (interaction 7:get PFZ), the component responsible for it (externally visible in this diagram as a Coverage Access Service from OGC Web Services), will assume different states in order to check the validity of requests to meet the restriction policies on area, season, vessel type/area combinations etc corresponding to the invariant schema. If found valid it will check currency of data whether the Quality of Service in the invariant schema is met. The results of these states will output the different states of the object ‘PFZ information’, snap shots of which can be seen in the static schema in the figure 6.1 below.

With respect to the test criteria at section 6.3.1 (2) , the interactions between the three computation objects referred to above, i.e. interactions numbered 7.1 and 7.2 in figure 6.1 (bottom), bring about changes to the state of the Object PFZ Information system. These changes are shown are in the dynamic schema at figure 6.2 below.

Figure 6.1 Juxtaposition of Invariant Schema, Dynamic Schema and Service Collaborations

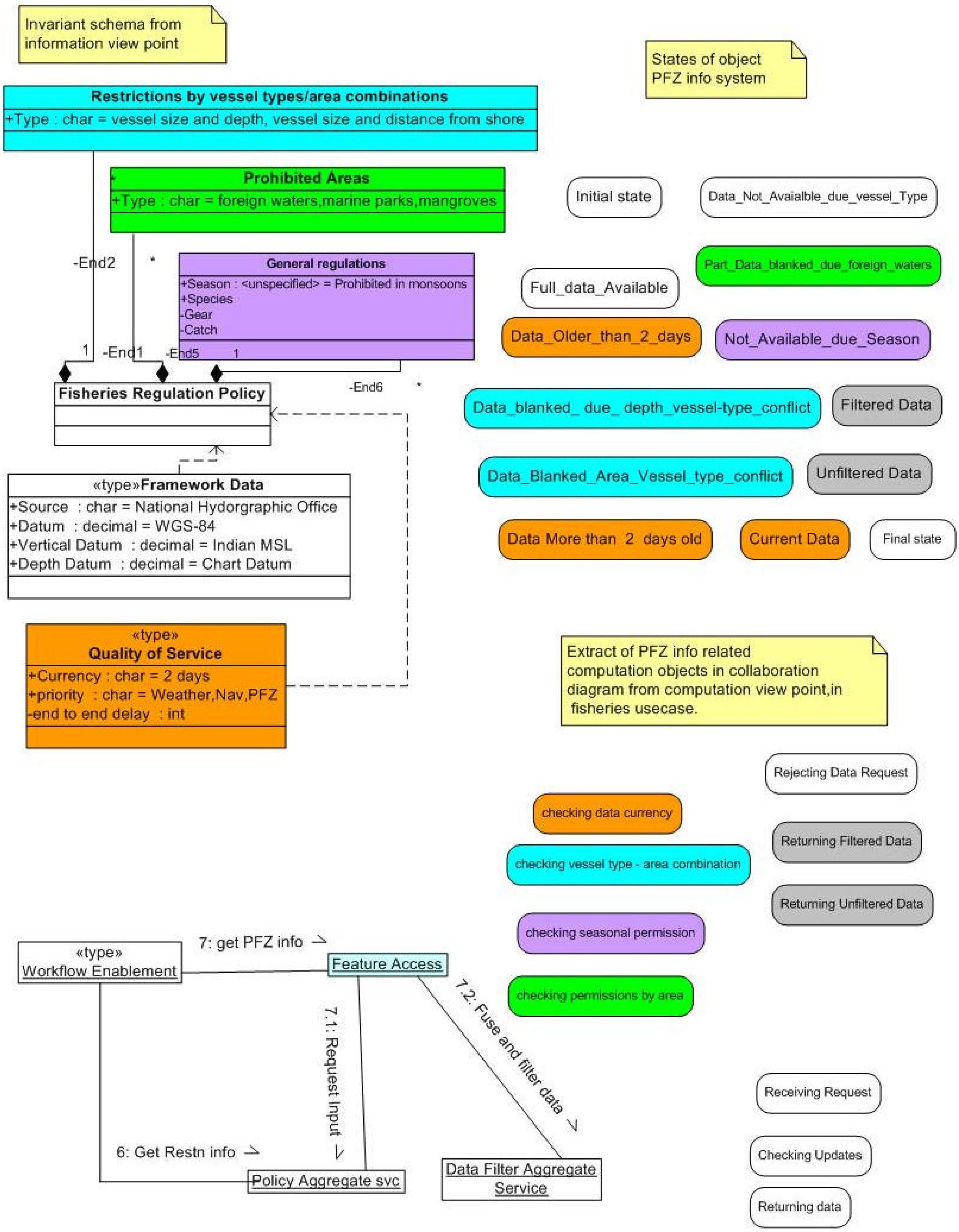
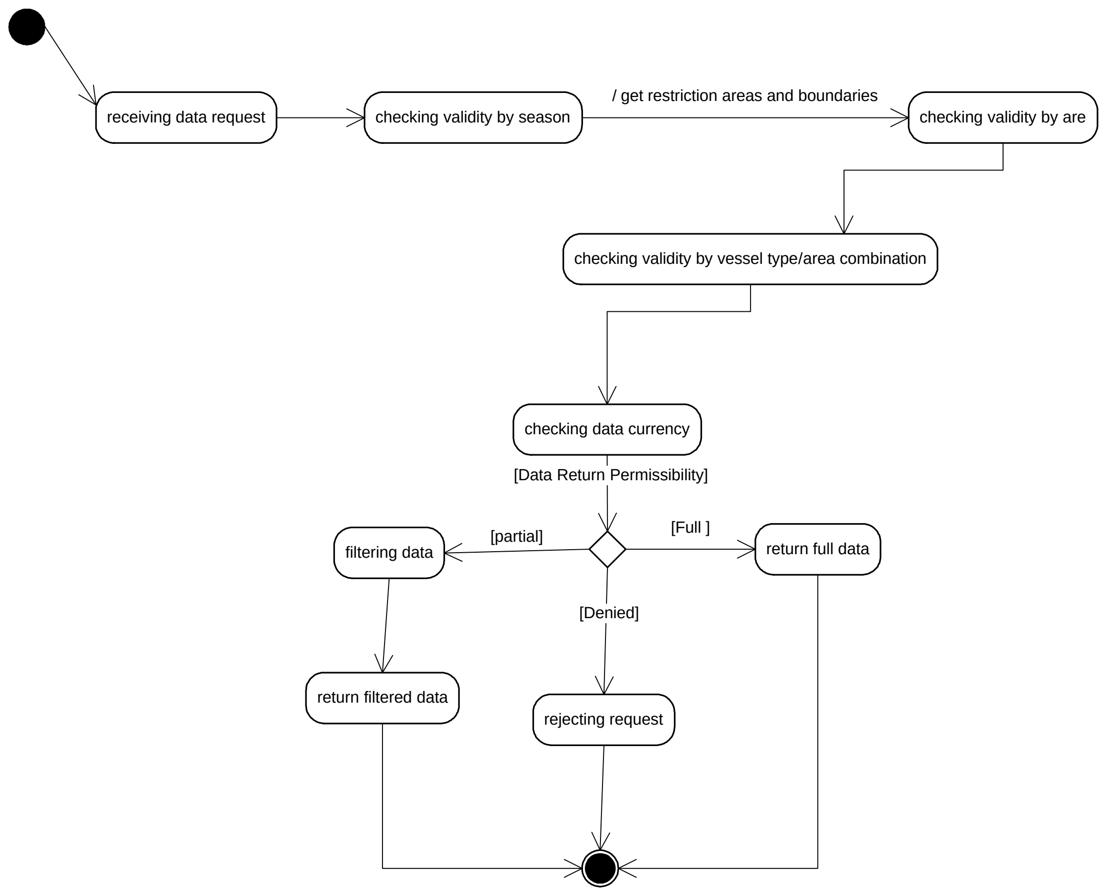


Figure 6.2 Dynamic Schema of Object PFZ Information System



6.5. Correspondences to Enterprise Viewpoint Roles and Policy

So far we far have dwelt on correspondence between Computation and Information viewpoints. Putman (5) has suggested a methodology of addressing consistency. One is that any dynamic behaviour is specified in information viewpoint must be supported in the computational viewpoint which is an abridged statement of what is covered in consistency rules above and already addressed above in some detail.

The second point mentioned by Putman relates to the need for explicit set of correspondences between enterprise, computational and information. One of the primary promises of RM-ODP is to seamlessly relate Enterprise Viewpoint to Computational and Information viewpoints. It is also a criteria for consistency. This is addressed by a model walkthrough , a common technique of model testing.

Table 6.1 The role I/O window

S No	Enterprise Objects	Roles
1	Fisherman User Interface	Input/output window, Map Display, GPS Position Provider
2	Potential Fishery Zone Data Information System	PFZ Data Provider PFZ Data Update Agent
3	Weather Information System	Weather/Warnings Notifier
4	Navigation Warning System	Navigation Warnings Notifier
5	Framework Data System	Hydrographic framework data provider
6	Marine Legal Regime Information System	Fisheries Legal Regime Advisor
7	Fisheries Subsystem Control	Fisheries subsystem Access Controller Quality of Service (QoS) Controller
8	GIS Services	Visualisation /analysis service provider
9	Geoportal Controller	Security Agent
10	Fisheries regulations repository	
11	Maritime boundaries data store	
12	Fisheries Restriction areas data store	
13	PFZ data store	

One walkthrough with an Enterprise Object

The model is now subjected to the testing technique of model walkthrough to test its logical consistency .

The usecase begins when a fisherman logs on to the Geoportal , requests for Fisheries Advisory Service and is returned with information. This is modelled through the RM_ODP specification concept of roles of I/O window, Map window, GPS Position Reader in the Enterprise View performed by the Enterprise Object Fisherman user Interface (Please see table 5.2). The roles are provided through and correspond to, the application services modelled in the computational viewpoint through the trading concept of service. (figure 5.6). The corresponding information viewpoint constructs are found in the static schema (figure 6.1) which shows different states of the User Interface Object. Log in information, Vessel registration details, fishing vessel database are captured in table 5.4 Sl. 2 and in the class diagram at figure 5.11, also relate to the roles we started out with in the EV. Similarly the architecture could be tested for consistency with respect to roles starting from the enterprise view.

A policy construct is now taken from the Enterprise view to test its correspondences in computational and information viewpoints.

The policy statement taken up for this test is drawn from section 5.1.11.2 in enterprise view - "Fishing vessels more than 30 metres in length shall not be provided with PFZ with PFZ data and seabed obstruction data in waters less than 30 metres in depth".

This policy is modelled in the enterprise view with the modelling concept ‘action’ namely ‘Mask Data’ in the business process model which is depicted as UML Activity diagram in the swimlane ‘GIS applications’ in figure 5.2. This action corresponds to two computational objects through the trading concept of ‘service’ namely feature manipulation service and ‘subsetting service’ [5] in the service chain modelled as a DAG. The computational interaction corresponding to the action ‘mask data’ is captured in the sequence diagram in figure 5.8 .

Further, the policy construct under scrutiny can be seen reflected in the invariant schema in the information viewpoint in section 5.3.1. The policy formalised as the invariant schema , further can be seen to determine the state, ‘MaskingforDepth' in the dynamic schema in figure 5.11.

6.6. Concluding Remarks

It is demonstrated by the test cases above that the rules of consistency specified in RM-ODP part [3] are met. for the purpose of the current study.

7. The Remaining Three Usecases in Brief

In this chapter are treated, three remaining usecases mentioned in Enterprise View of the Geoportal in Chapter 4 , figure 4.2. These are Coastal Zone Management support service, Weather Service and Hydrocarbons Production Support Service. Methodology outlined in chapter 3 is used in abridged form.

7.1. Hydrocarbons Production Support Service Usecase (from Hydrographic Services)

7.1.1. Enterprise View

7.1.1.1. Objective

This usecase is a constituent of Hydrographic Services Usecase. Objective of the former is to provide hydrographic framework data, thematic information, sea state and water column dynamics data, navigational safety information with related decision support services for exploitation of non living resources on the sea bed specially hydrocarbons.

7.1.1.2. Use Case Scenario

The government has decided to increase domestic production of hydrocarbons by promotion of offshore production. It has leased out several offshore areas to private companies for exploration and production rights. The private company has carried out exploration, and has struck oil. It has been decided to lay an oil pipeline from the production well-head leading ashore.

7.1.1.3. UseCase Walkthrough

The Operations manager of an offshore oil Production company has obtained preliminary information on bathymetry and seabed morphology to enable oil prospecting operations. He/She also obtains the current and forecast sea state and weather report.

This usecase starts when the oil company’s planning manager wishes to carry out a desktop study to determine the best landing site for the oil pipeline considering several economical, ecological and engineering issues. Based on the study a proposal is made and submitted to the local CZM authority. Once the landing site is decided and approved, a survey consultant is hired to carry out a desktop study to identify the best submarine pipeline route to the landing site. The geoportal is consulted for bathymetry, on nature of seabed and sub-bottom, and currents on sea surface and the water column to establish a tentative best route. This will amount to large savings in time and cost in actual route surveys.

The following table identifies the roles, their functions and type of associated objects in accordance with structuring rules of RM-ODP enterprise view.[3]

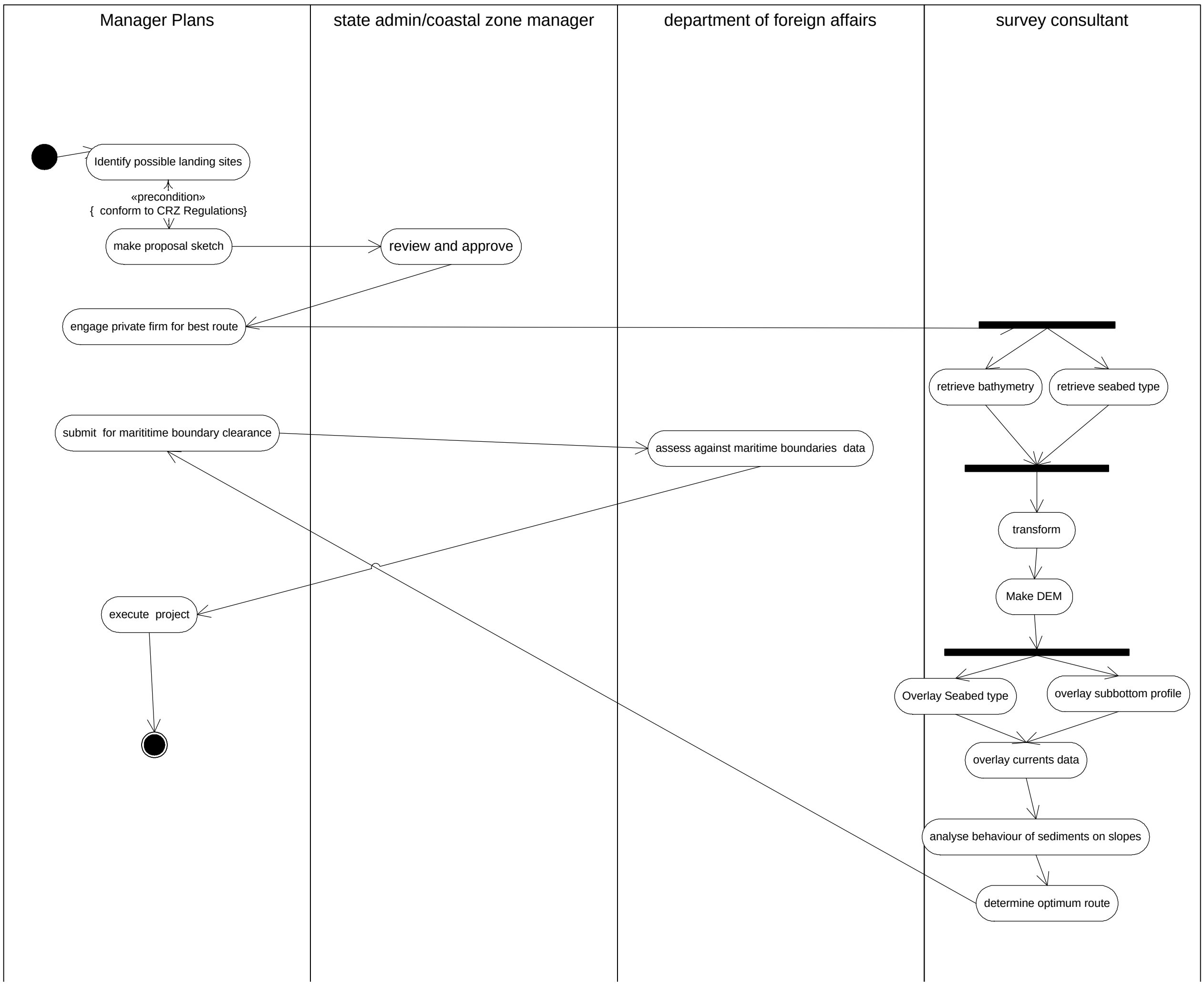
Table 7.1 Hydrocarbon Production Support Services – Roles and Actions

Object Type	Role	Actions
Person	Offshore Oil production Company – Manager (Plans)	Desktop study to determine possible landing site for pipeline from production platform. Submit proposal to Coastal Zone Management Authority.
Person	Survey consultant	Obtain framework data and oceanographic data for desktop study to determine tentative route.
Software	Navigation Information Agent	Provide info on navigation hazards, shipping routes, weather data, sea state, electronic charts, navigation warnings, chart updates, Catalogue of Navigation Charts, Real time flows in harbour entrance channels and at berths.
Software system	Framework Data Store	Provide updated and accurate framework data - Bathymetry (grid and DEM), Seabed type (grid), Lighthouses, Shipping lanes, permanent Seabed obstructions, High water line, low water line, offlying rocks, drying features, islands, outline of permanent coastal or offshore infrastructure.
Software	Marine Cadastre Agent	Provide information on - Territorial Waters and Contiguous Zone Offshore Marine Restricted Areas Prohibited Anchoring Zones Submarine Exercise Areas Fishing Prohibited Areas Dumping Grounds Ammunition Dump Sites Low Water Line

7.1.1.4. Processes

The processes associated with the Usecase are captured in a UML activity diagram in figure 7.1 below.

Figure 7.1 Business Process – Activity Diagram - Usecase Hydrocarbons



7.1.1.5. Policies

The following policies directly impinging on the Usecase are identified :-

- All data provided on the geoportal is obliged to conform to the security guidelines of the Ministry of Defence.
- Public access to Oceanographic data on a grid closer than 10 nautical miles is prohibited.
- It is obligatory for all users to register with the geoportal.
- The Data Provider is obliged to provide quality metadata and is responsible for it.
- Users are permitted to make commercial use of graphics prepared while analyzing the data including reproduction and publishing. They are however obliged to acknowledge the Geoportal.
- Must be governed by guidelines of the Ministry of Hydrocarbons. Oil Pipelines should not pass through marine protected areas or ecologically sensitive areas.

7.1.1.6. Preconditions

The following preconditions apply :-

- The user is registered with the service within 5 days of commencing operations in Indian Exclusive Economic Zone (EEZ).
- Production well head identified.
- All databases specially framework databases are adequately populated.

7.1.1.7. Post Conditions

- Pipeline landing site identified to make proposal.
- Tentative oil pipeline route from production well head to landing site determined and mapped.

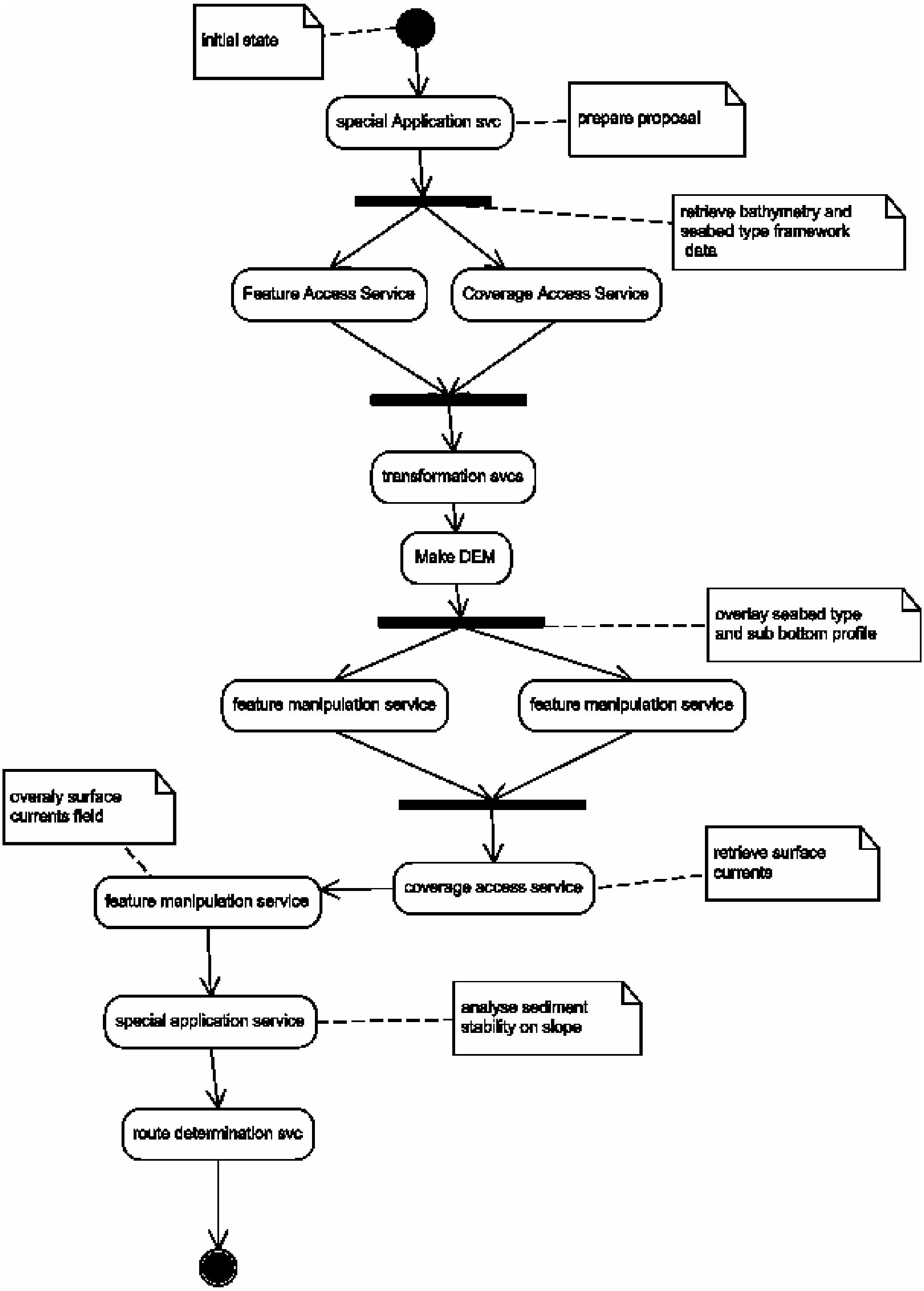
7.1.1.8. Invariants

- No activity shall be carried out in foreign waters, unless specifically permitted.
- The currency of bathymetric data shall not be older than 6 hours.
- Priority shall be accorded to weather and navigation services in that order.

7.1.2. Computational View

The business processes and roles can be realised as a set of services in a service chain. The services are from the own service framework. Those not found in this framework have been picked up from ISO 19119 [7]. The service chain to realise the use case has been modelled as Directed Acyclic Graph using a UML Activity Diagram in figure 7.2 below.

Figure 7.2 Service Chain Directed Acyclic Graph - Hydrocarbons Usecase - UML State Chart Diagram



7.1.3. Information View

7.1.3.1. Information Objects

Some of the important information objects are Low Water Line (line) , Exclusive Economic Zone Boundary (line), Exclusive Economic Zone (Area), Spot Depth (point), Spot Seabed Type, Bathymetry (coverage), Seabed type(coverage), Currents (coverage), Wind, Waves – significant height, periodicity, Seabed DEM, sub bottom type profiles, sub surface currents.

7.1.3.2. Invariant Schema

The vertical datum for depths shall be the chart datum depicted on the hydrographic chart for depths less than 100 metres. For depths more than 100 metres it shall be the Mean Sea Level.

The Geodetic Datum for all data shall be WGS 84.

The line defining the Exclusive Economic Zone (EEZ) shall be determined with reference to the Low Water Line. The EEZ (Exclusive Economic Zone) is a strip of the sea 200 nautical miles from low water line to sea ward.

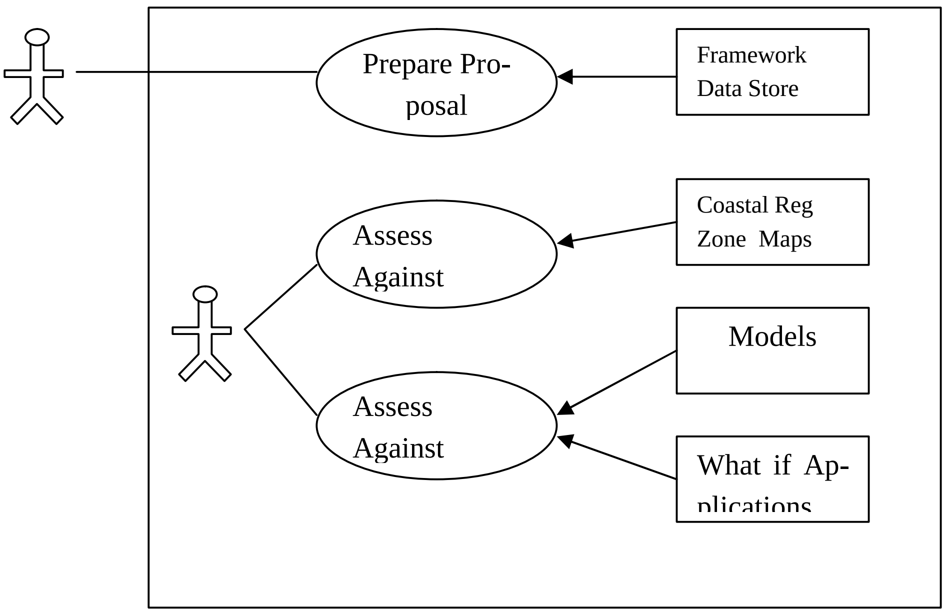
7.2. Coastal Zone Management Support – (Port Site Approval) Usecase

7.2.1. Enterprise Viewpoint

7.2.1.1. Scenario

The usecase diagram in figure 7.3 below shows a refinement of the 'coastal zone management- Approve Port Site Proposal' usecase.

Figure 7.3 Enterprise View – UseCase Diagram – Port Site Approval



This usecase typifies another important area of concern identified in chapter 4. It relates to Decision Support in assessment of proposals for Coastal Infrastructure in the backdrop of environment , economic and engineering factors. Govt of India has promulgated Coastal Regulation Zones Notification under the Environment protection Act 1986. This notification classifies a 500 metre wide coastal belt from high tide line into four zones with different development policies eg CRZ1 comprises all ecologically sensitive areas where no human activity is permitted. CRZ 2 is zone already developed upto the shoreline where no construction seaward of existing roads is permitted. The notification intends to balance the mutually conflicting requirements of human settlement, industrialization, biodiversity protection, pollution control in the coastal zone. This usecase is intended to support decisions on land use, by offering framework data, related services and applications. Some of the stakeholders are Coastal landowners, Private Port Developers, CRZ Planners (State Govt) , CRZ Implementers (Local Govt). The aim is speedy and accurate assessment of coastal infrastructure development proposals against CZM plans.

This Usecase begins when a private party submits a proposal for building a new port. The proposal is evaluated by the state government in accordance with the State Coastal Regulation Zonation Plans maintained on CRZ plans on scale 1:25 000. They are implemented by local administration using implementation plans on scale 1:5000. The plan will be assessed against coastal topography/morphology and near shore hydrography. In addition several models will be used such as wave model to assess impact on coastal erosion, environment impact assessment model , econometrics model , transportation network. This would require access to framework databases, distributed thematic data and modelling applications.

Table 7.2 captures the roles, actions and associated object types. the role framework data agent in the table, accesses data from framework data service which is a constituent use case of hydrographic services usecase. It is clear that the modelling application is not onboard the geoportal

Table 7.2 Coastal Zone Management Support Service –Roles and Actions

Object Type	Role	Actions
Person	Private port builder	Submits proposal for new port.
Person	Coastal Zone Regulation Authority	Lay policy on Coast Zone Regulation, Pollution, Exploitation of Fish Receive infrastructure development proposals Assess Infrastructure Development proposals against these policies.
Software system	Framework Service Agent	get framework data – high tide line, bathymetry, topography, vertical and horizontal datum. fusion of land and sea data. get sea-level rise data
Software system	Cadastral Info system	Provide planning and implementation CRZ maps, overlay on proposed site map.

Object Type	Role	Actions
Person	Private port builder	Submits proposal for new port.
Software sys	port site selection modeling application	Assess by running following models :- Environment Impact Assessment Wave Model for Coastal Erosion Transport Network model Econometrics model

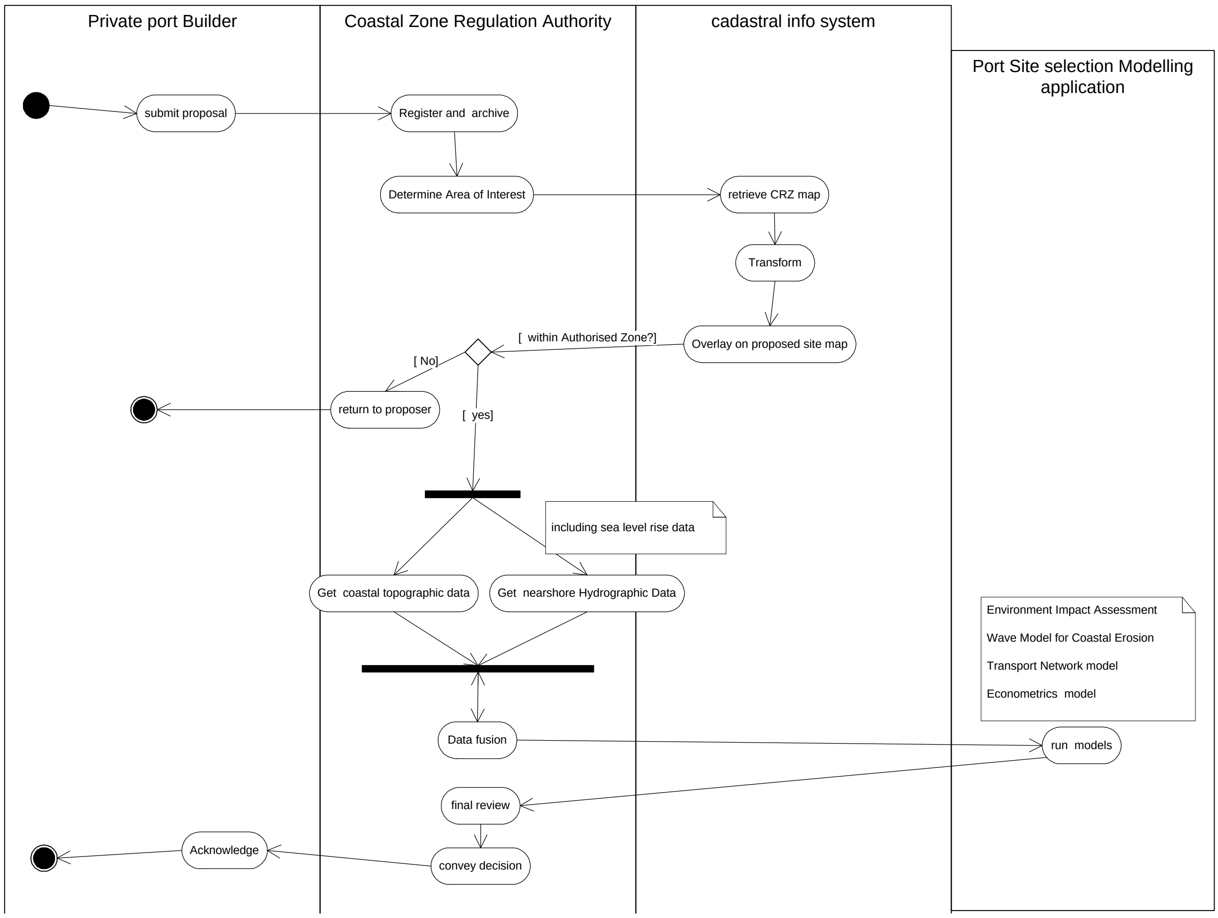
7.2.1.2. Preconditions

CRZ maps are available with Cadastral Information System

7.2.1.3. Processes

The processes of the Usecase are captured in the UML activity diagram shown in figure 7.4 below.

Figure 7.4 The processes of the Usecase are captured in the UML activity diagram



7.2.1.4. Post condition

A verdict on acceptance or otherwise of the proposal for building new port as proposed, from the state govt.

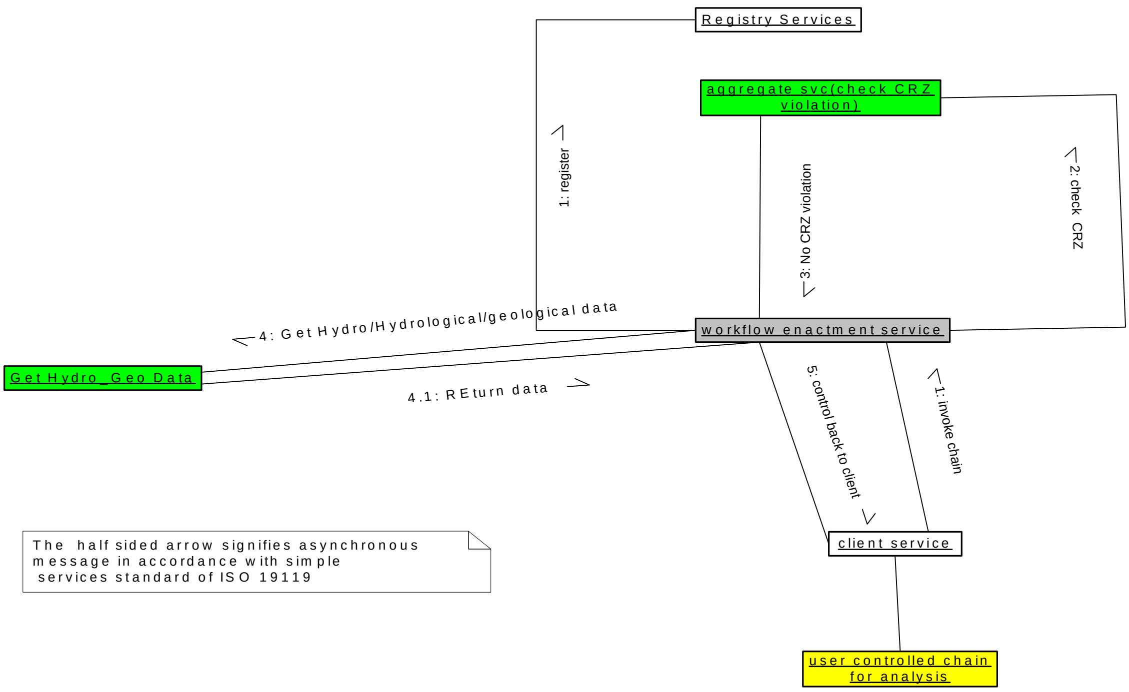
7.2.1.5. Policies

- This service shall be governed by Govt of India , Ministry of Environment notification on Coastal Regulation Zones 1986.
- It is obligatory that the CRZ state planning maps be prepared on scale 1:25, 000 and CRZ local implementation maps on scale 1 : 5000.
- It is prohibited to base decisions on maps enlarged to more than 10% of the production scale.
- It is obligatory to bring all maps to the Everest Datum before any analysis or decision making.
- It is obligatory that accuracy of positioning for infrastructure plans drawings is better than 20 cm horizontally and 1 cm in the vertical plane. The vertical datum for all construction ashore shall be Indian mean Sea Level .

7.2.2. Computational View

The collaboration diagram in figure 7.5 depicts the service chain which realizes the roles/actions and processes identified in enterprise view. The sequence of collaboration starts with (1) when the port developer through the client service at bottom part of the diagram , submits a proposal for developing a port for site approval to the state authority. It activates ISO 19119 workflow enactment service [5] which registers the proposal through a registry service (2). The workflow service activates an aggregate service which determines if there is violation of CRZ regulation in sitting the port (3).If there is violation, control is returned to client service. If not, hydrological/geological data is retrieved via message (4) . Next at (5) a user defined chain analyses the site suitability further by using this data, models identified in activity diagram at figure 7.4 (last swim lane) , and special applications. Assessment results are conveyed to the user via the client service at (6).

Figure 7.5 Coastal Zone Management – Port Site Approval Usecase – Service Chain – UML Collaboration diagram



7.3.

Weather Services – UseCase

7.3.1. Scenario

India is highly dependent on the Monsoons for agriculture. Accurate prediction of the Monsoons is always a central theme of most scientific activity. It is also necessary for flood warnings. Further, tracking of weather systems are equally necessary to track tropical revolving storms and other systems.

The Department of Ocean Development has deployed several buoys in shallow and deep waters all over the North Indian Ocean. Agencies of the department also coordinate deployment and collection of ARGO floats in the area. An ARGO float is a oceanographic sensor float which after deployment goes down till a certain depth and surfaces. Once on surface it transmits its data. This data is collected by the coordinating agency and distributed to other national and international agencies participating in the GOOS (General Observation of the Seas) programme of IOC (International Oceanographic Commission).

In addition the Indian Ocean is covered by satellite Imagery by the Indian Space Programme. Further, there are met stations all along the coast and on islands. It is intended to provide a quick and reliable means to make this data available to the concerned agencies for analysis, prediction, warnings and dissemination.

7.3.2. Usecase Walkthrough

The usecase starts with in site oceanographic measurement data collected by a data centre of Department of Oceanography. This data is made available to the geoportal. In addition National Remote Sensing Agency (NRSA), makes the latest satellite imagery imaginary data and products available on the portal. IMD (India Met Department) in addition to its own network of met stations retrieves the aforesaid data from the Geoportal for periodic predictions. The same channel is also used for detection, monitoring and prediction of the movements of tropical revolving storms.

7.3.3. Enterprise View

7.3.3.1. Objective

To enable exchange and assimilation of satellite remote sensing observations, real-time observations from ocean data buoys and floats and land based meteorological stations including radar stations for effective weather forecast.

The resulting forecast should be accessible from the geoportal both in push and pull mode

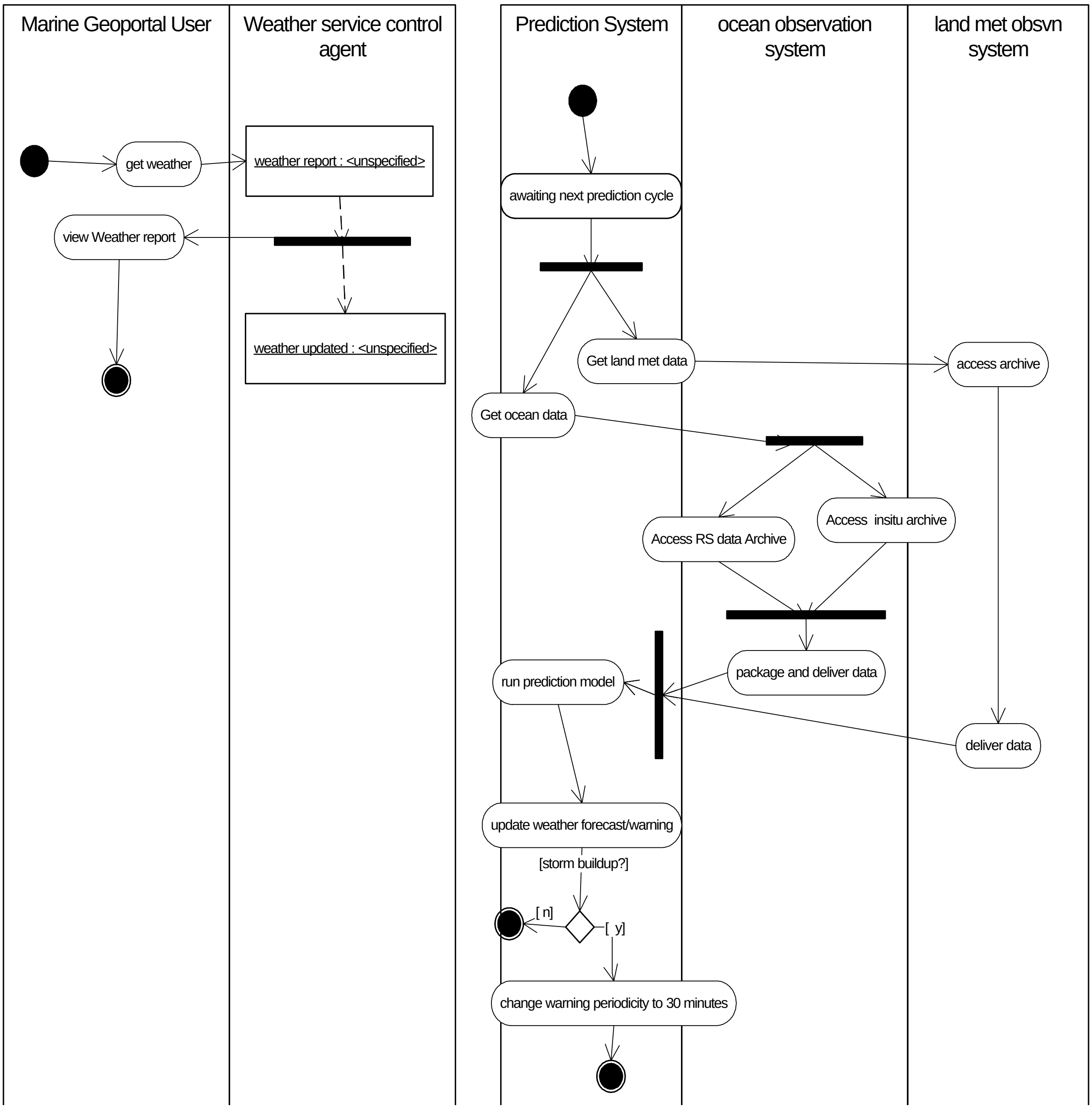
7.3.3.2. Scope

The scope of the usecase is covered by the following table of roles/ actions and the usecase diagram in figure 7. 6 below. The process model shows how a complex string of observations required for weather forecast can be put together.

Table 7.3 Weather Service – Roles

Object Type	Role	Action
Software System	Weather Prediction Agent	Access met data, run prediction models, provide forecasts.
Software system	RS Ocean Observation agent	Collect archive and provide Remote Ocean observation data.
Software system	In-site ocean observation agent	Collect , archive and provide Ocean Buoy Data
Person	Coast Disaster Manager	Storm Surge prediction

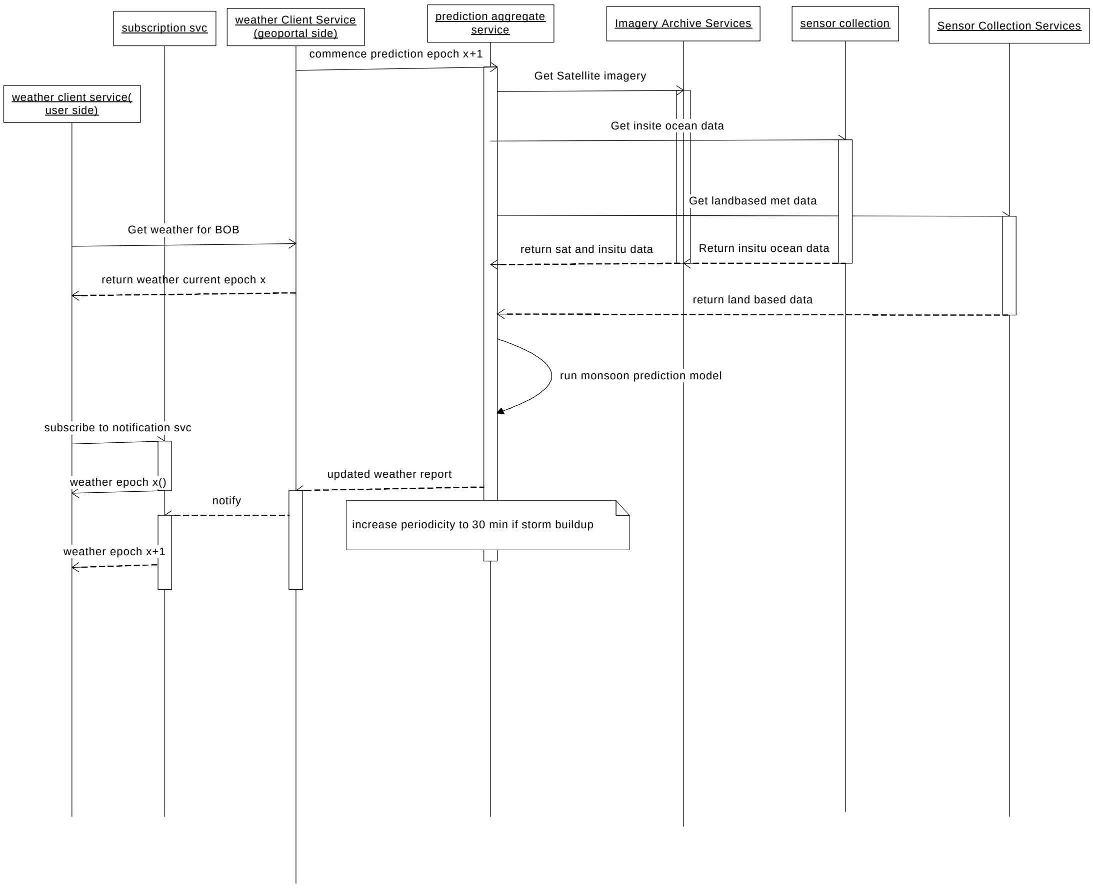
Figure 7.6 Usecase Weather Services- Process Model- UML Activity Diagram



7.3.4. Computational View

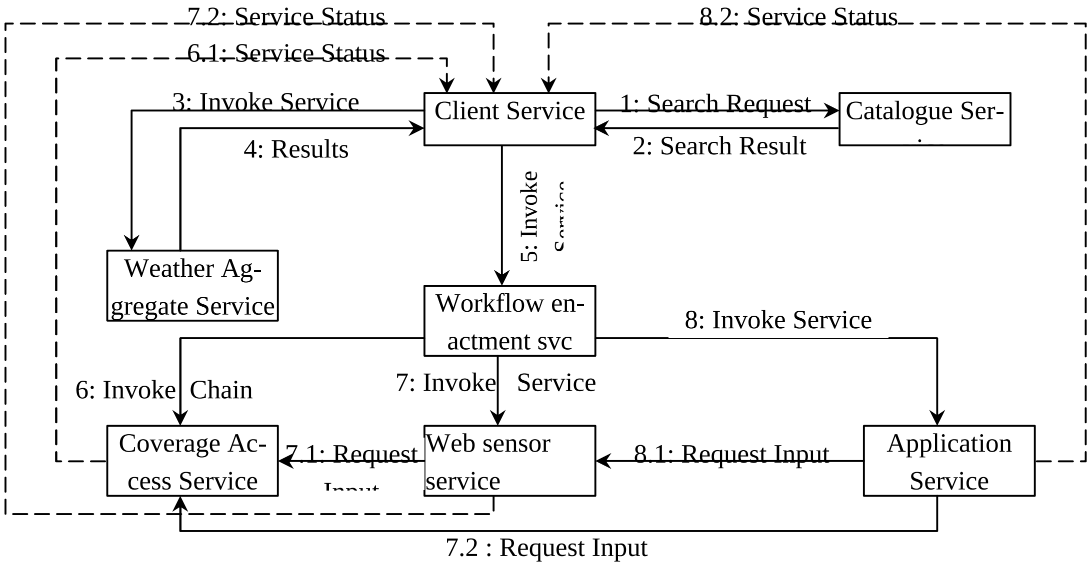
The services required for the weather prediction processes and dissemination together with their interactions are depicted in UML sequence diagram in figure 7.6 .

Figure 7.7 **Usecase Weather Services- Process Model- UML Sequence Diagram**



Next a chain in Figure 7.7 below depicts the mechanism of weather warning data and storm surge prediction by the coast zone administrator, through the Weather Service usecase. The Coast administrator discovers a suitable service at (1) and (2), retrieves weather through a weather aggregate service (3), requests for storm surge prediction (5) (for storms making landfall), which activates a workflow service. The workflow service invokes a Coverage Access Service (CAS) to retrieve high resolution wind and pressure fields (6). Next a web sensor (WSS) is invoked to get sea level data, river flow data. (7). With this data a special application is invoked (8), which runs a storm surge application to produce storm surge levels for next few days. Also an Inundation model which provides inundation levels based on the storm surge.

Figure 7.8 Chain for Monsoon and Cyclonic Storm Prediction/Coastal Zone Manager- UML Collaboration Diagram



7.4. Geoportal Support Services Usecase

These are services local to the geoportal mainly for administration. The roles and actions are captured in table 7.5 below. This is followed by policies. This system has not been captured further for constraint of space and time. Also this system has many commonalities across application domains.

Table 7.4 Geoportal Support Services

Object Type	Role	Actions
Software system	Admin Agent	Control Access, Coordination, security, Quality Control
Software system	Clearing House Agent	Provide Discovery services
Software system	Security Agent	Authentication
	NSDI Manager	Defines NSDI policies and Business Processes
Software system	Policy Manager	Maintain policy and regulations affecting operations of the Geoportal.

7.4.1. Policies

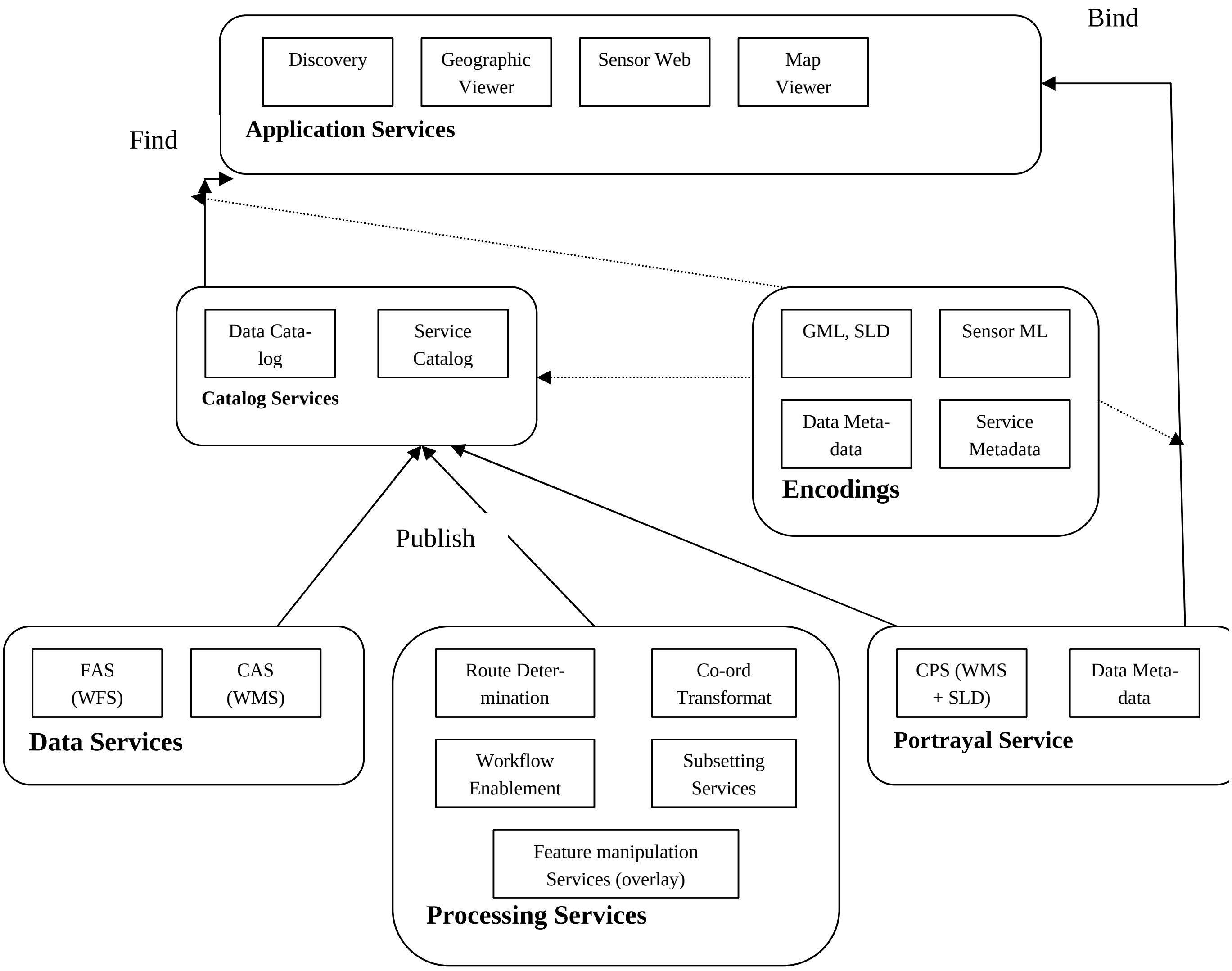
- It is permitted to charge upto 50% of the maintenance costs of the system from the user.
- It is obligatory that Framework Data is provided only by authorized government agencies based on consensus content models for identified framework themes.

- It is obligatory that bathymetric data provided as framework data complies with International Hydrographic Organisation (IHO) standard S-44 Order 2 [24].
- The Geoportal is obliged to be built primarily around OGC Web Services standards [1] and ISO 19119 [5].
- It is obligatory that all except framework data and that required for geoportal operations, shall reside with the service provider who shall be responsible for its maintenance and access by users.

7.5. Service FRAmework

This chapter is concluded by identifying a Framework for the services identified in the usecases addressed. It is based on the experience and requirements of the Marine geoportal but modelled on the OPenGIS Web Services Service Framework (OSF) in OGC Reference Model [1]. It is a profile of the OGC /ISO services. It’s value lies in the fact that it is small subset which draws the parameters of the system in a crucial respect and allows focussed activity on system development.

Figure 7.9 Service Framework for Marine Geoportal



8. Conclusion and Recommendations

This chapter provides a short summary of the work undertaken in this thesis. This is followed by presenting some conclusions and observations and finally recommendation for further research.

8.1. Summary

The study has developed reference architecture for marine Geoportal in the contexts of an NSDI. The Geoportal is intended to be based on web services employing the standard developed by ISO tc 211 and OGC. The reference architecture is based on RM-ODP (Reference model of open distributed processing) which provides patterns of reasoning by a system of common concepts. This is a ISO/IEC standard also adopted by OGC for its web services incentives.

The study has been motivated by the need for developing reference architecture for SDI Geoportals. Marine sector in NSDIs, has received less attention. Very limited use of RM-ODP is seen in development of SDI Geoportal architectures. RM-ODP does not define any notations. However UML suggests itself to be a modelling language suitable for RM-ODP. Taking these three factor into account, reference architecture for a marine Geoportal has been developed based on RM-ODP using UML.

The thesis commences with an introduction to Services in chapter 2 which includes a review of service, chains and its three primary types.

As RM-ODP does not specify any methodology for its usage, this has been established in chapter 3. The methodology was developed based on the interpretation of the RM-ODP standard in context of the marine Geoportal. This interpretation and development was aided by existing additional literature, but the methodology developed stands on its own.

A quick insight into the architecture development can be found in the following description based on research questions.

- For an initial Marine SDI Geoportal for Less Economically Developed countries what could be the priority areas of concern ?
    - This has been done as an exercise in order to identify a subset of the marine user environment based on which the marine geoportal was made. The important areas of concern have been identified from authentic sources. The purpose was to provide a realistic and practical backdrop in which to develop the architecture. The areas identified are widely relevant and identified through literature research, this aspect is peripheral to the thesis.
- What Business Goals, User’s requirements, constraints and Processes of the Marine Geoportal can be identified from the standpoint of the User and system environment?

  - This question was asked to develop a User's view of the system. This model has been developed through the RM-ODP enterprise viewpoint. It is found that for detailed target architecture more viewpoints may be necessary to refine the separation of concerns.
- How can the requirements at question 2 above, be realized through chained services to satisfy User Requirements.
  - Through the computational viewpoint the services required to realise the user requirements have been identified. These services have been modelled using directed acyclic graphs (DAG). The chains have been further modelled for their collaborations and interactions. Types of Service chain has been suggested based on chain modelling criteria, user requirements and other criteria identified. Possible Chain use has been identified and few issues of service distribution have been identified and specified. For example location and management of framework services.
- What is the design criteria for modelling chained services?
  - It is found that the architectural concepts of RM-ODP like composition, decomposition, type, basic modelling concepts of action, interface, activity, behaviour (action of an object) and user side principles of user competence, end use of chain, type of data, data source, are some important criteria. Some of these have gone into designing service chains for the usecases in this work.
- What service framework can be developed for the geoportal as a profile of OSF (OGC Web Services, Service Framework)?
  - The services required for this subset of the Marine UoD , has been identified and placed in a framework, as a profile of OGC Web Services, Service Framework (OSF). A few services are not reflected in OSF but are part of OGC service architecture abstract standards, which is identical to ISO 19119 [5]. So while this may not be immediately implementable it reflects a target architecture.

8.2. Conclusions

The following conclusions were drawn from this research :-

The approach of separation of concerns was found to facilitate the process of architecting. The Enterprise specifications was found reflected in all other viewpoints through linkages of common concepts with precise semantics on which RM-ODP is based. For example concepts of policy carried throughout the architecture as constraints on interaction of objects. Both policy and constraints share the same semantic language, evenwhile the former is used to capture the business requirements while the latter is used in the systems environment.

It was realised how RM-ODP allows use of views additional to the standard five view points. In this study two additional views were adopted to establish a methodology for developing reference architecture. These were the Usecase view and the Analysis view of the Unified Process. It gives a good insight into the flexibility RM-ODP offers in developing different methodologies. In this manner it sets itself apart from other methodology dependent architecture techniques.

UML adds more clarity by a formal method of visualization and documentation.. It also lends the rigour of a widely used software architecture modelling language. As most ODP system architectures are software intensive, UML is considered best suited for adoption as a language integral to RM-ODP. This is expected to strengthen RM-ODP and remove semantics incompatibilities between system specifications because of different notations. This is specially important since there is a multitude of notations with its own complex syntax.

The concept of invariant schema was found one strong central binding factor which determine much of the architecture frame work through the common linkages of RM-ODP concepts. This provides one of the central pillars on which consistency is tested. The study provides good insight into this aspect.

As promised in the literature the reference architecture demonstrates how the system requirement from the user viewpoint can be captured in a specification language which seamlessly interacts with, and corresponds to the system specifications in terms of functional components and information content, along with their structure and behaviour.

Offers a means to model system entities, roles, processes, atomic action, and relates them to their corresponding functional components of services. Direct linkages between service components and dynamic states of information objects could be determined

Early on , the RM-ODP standard allows grouping of resources within the enterprise for implementation in the Engineering viewpoint which focuses on distribution.

A non trivial example of the use of RM-ODP for a major area of application in the domain of SDI, for a very wide user community of Geospatial data and services has been established. While RM-ODP was found to be both too complex and too simple. It is complex because of its ability to define a system at any level of detail. It could also be simple as everything is based on a few primitives distilled from a knowledge base of decades. Illustrations would be necessary for this standard to made use of more in the field of Geoinformatics. This work has attempted to contribute in that direction.

It is considered that RM-ODP in conjunction with UML, be adopted by all SDIs as a standard for capturing and specifying architectures of the SDI elements such as Geoportals. Other than internal benefits , it is expected that benefits will accrue to the efforts at realizing a Global SDI.

This Reference Architecture could form the basis or inspiration for a similar architecture for an NSDI Geoportal. This is specially true of countries where SDI is in the transition phase from concept to implementation eg India.

8.3. Further Research

The propositions made in this thesis were limited to the RM-ODP. While it is an international standard already adopted by OGC and ISOtc211, it would be useful to examine what profile of the framework is necessary to suit Geographic distributed systems. This means making a subset and adding concepts specific to Geospatial domain not present in RM-ODP. In addition, methodologies to use RM-ODP with UML profile for EDOC (Enterprise Distributed Object Computing) can be developed. There is a distinct necessity to accumulate more experience in architecting Geoportals and related Geo systems using RM-ODP and UML in order to leverage the effort of integrating Geoinformatics with the world of IT.

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Glossary

Activity: A single-headed directed acyclic graph of actions, where occurrence of each action in the graph is
made possible by the occurrence of all immediately preceding actions (i.e. by all adjacent actions which are closer to the head).

API Application Programming Interface

Architecture (of a system): A set of rules to define the structure of a system and the interrelationships between its parts (RM –ODP part 2)

Abstraction: The process of suppressing irrelevant detail to establish a simplified model, or the result of that
process.

Atomicity: An entity is atomic at a given level of abstraction if it cannot be subdivided at that level of abstraction.

Behaviour (of an object): A collection of actions with a set of constraints on when they may occur. A behaviour may include internal actions. The actions that actually take place are restricted by the environment in which the object is placed.

Business Process is defined as a set of one or more linked procedures or activities which collectively realize a business objective or policy goal, normally within the context of an organizational structure defining functional roles and relationships. (wfmc 96 as defined in Morales 1998 workflow oriented design)

Component. Software that packages the client or server implementation of a service and can provide the realization of a set of interfaces. A component consists of software code (source, binary or executable) or other equivalents such as scripts or command files.

Contract: An agreement governing part of the collective behaviour of a set of objects. A contract specifies obligations, permissions and prohibitions for the objects involved.

Dynamic schema:A specification of the allowable state changes of one or more information objects, subject to the constraints of any invariant schemata.

Domain An <X> Domain is defined as “a set of objects, each of which is related by a characterizing relationship <X> to a controlling object. Every domain has a controlling object associated with it. The controlling object can determine the identities of the collection of objects which comprises the associated domain.”(RM ODP 2).

Environment Contract: A contract between an object and its environment. This contract describes the requirements placed by the object on its environment and vice-versa particularly QoS constraints.

Framework Data. Data that serves as a reference to integrate feature and coverage data of disparate themes and variable quality.

Invariant A predicate that a specification requires to be true for the entire life time of a set of objects. RM-ODP part 2 . It is a specification concept.

Operation: An interaction between a client object and a server object which is either an interrogation or an announcement.

Policy A set of rules related to a particular purpose. A rule can be expressed as an obligation, a permission or a prohibition.

Post condition. A predicate that a specification requires to be true immediately after the occurrence of an action.

Precondition: A predicate that a specification requires to be true for an action to occur.

Quality of service. A set of quality requirements on the collective behaviour of one or more objects. Quality of service may be specified in a contract or measured and reported after the event.
(Note - Quality of service is concerned with such characteristics as the rate of information transfer, the latency, the probability of a communication being disrupted, the probability of system failure, the probability of storage failure, etc)

Role Identifier for a behaviour, which may appear as a parameter in a template for a composite object, and which is associated with one of the component objects of the composite object.

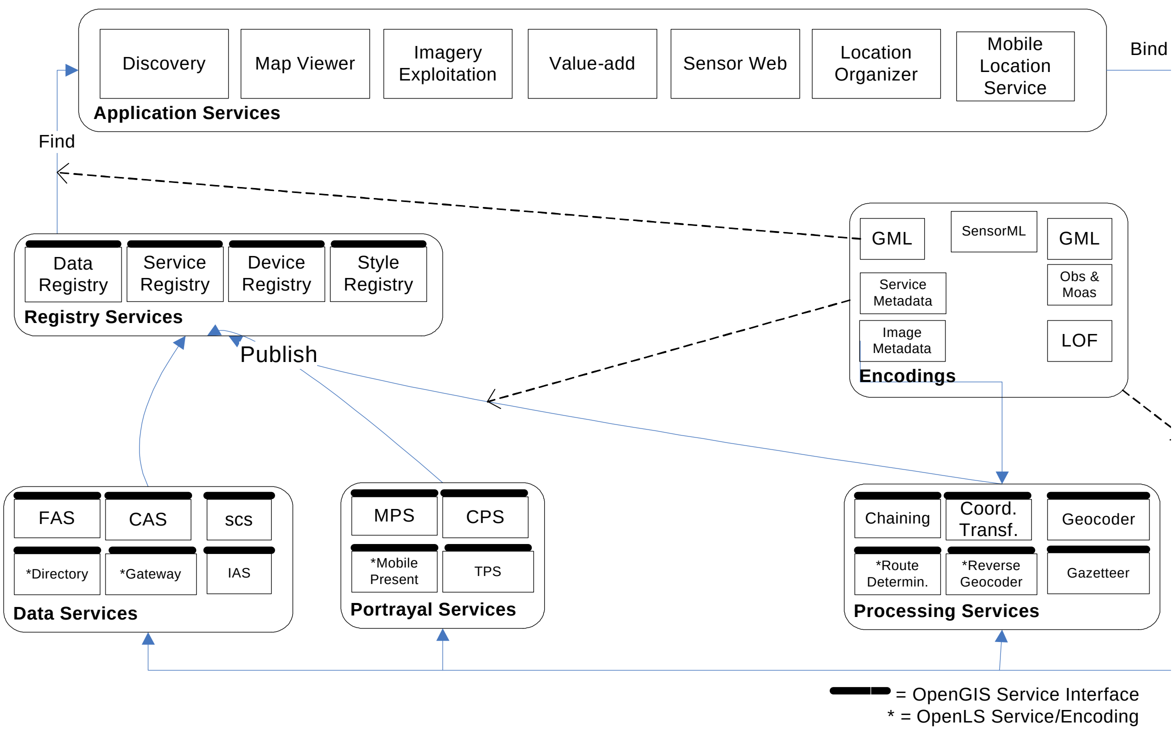
Static schema: A specification of the state of one or more information objects, at some point in time, subject to the constraints of any invariant schemata. Behaviour in an information system can be modelled as transitions from one static schema to another, i.e., reclassification of instances from one type to another.

Signal: An atomic shared action resulting in one-way communication from an initiating object to a responding object. A signal is an interaction.

System: Something of interest as a whole or as comprised of parts. Therefore a system may be referred to as an entity. A component of a system may itself be a system, in which case it may be called a subsystem.

Appendix A - Chained Services – More Details

A.1 OWS Service Framework [1]

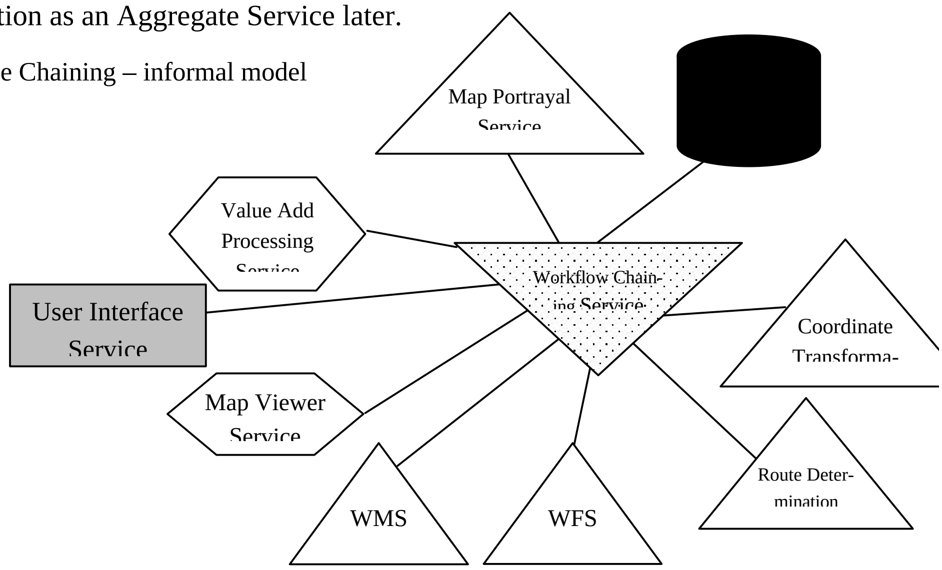


8.4. A2 Types of Chain

A User Controlled Chain

A User Controlled Chain is where the user directly invokes the required services as per a user defined sequence. When a certain sequence is found acceptable it may be captured as a process and stored in a process repository for invocation as an Aggregate Service later.

Figure Workflow controlled service Chaining – informal model



Workflow Controlled Chain

Fig 2.5 above depicts a workflow controlled service chaining where a chaining service passes a process model and required output and other necessary input to a workflow service. The workflow service retrieves the required process model from a repository and calls data, processing portrayal and other services as required. It consults the registry service as necessary for services not mentioned in the process model. Errors and status are communicated to the user.

Figure Workflow Reference Model

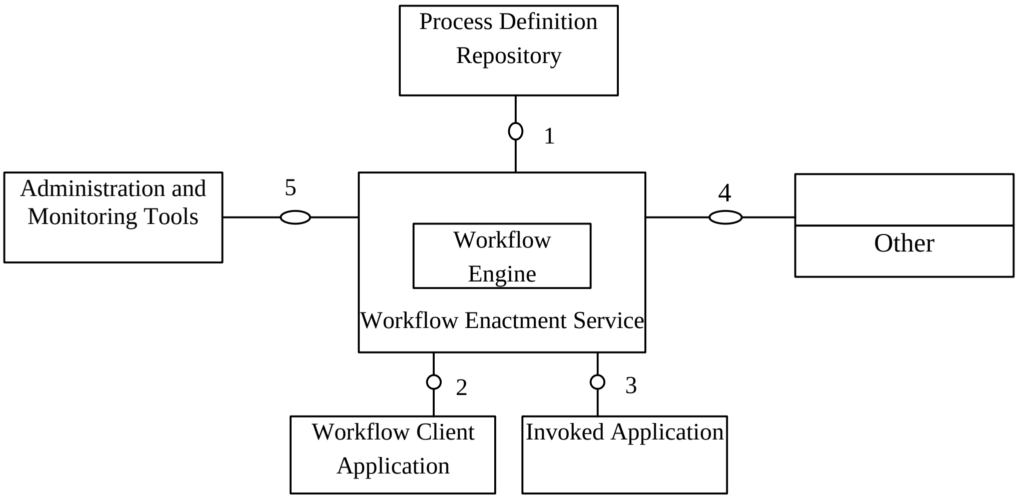
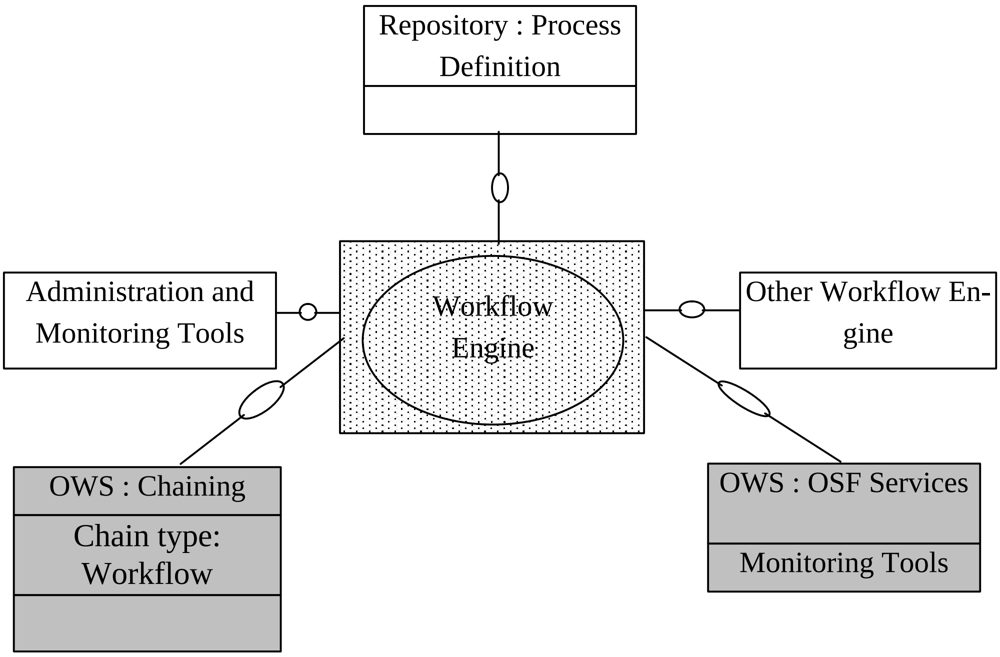


Figure Workflow Controlled Chaining Service within the Workflow Reference Model



In the OWS Service Framework however the workflow service is not currently supported. (2004). The workflow reference model (Fig 2.6) has been adapted to realize this chaining concept (fig 2.7). Here the single process model is replaced by a Process Model Repository. The primary functions of orchestrating the chain is undertaken by a workflow engine from the domain of workflow technology in Business Process Management. The chaining service in this case is merely the workflow client.

The task request is made to the chaining service which acts as a façade and process it with appropriate parameters including the process model details to the workflow engine. The wfms chooses the appropriate model from the repository, invokes required services and application of the OSF, and passes the results back to the chaining service. If the called process model or application / service is not available it may invoke other workflow services across the interfaces under development by wfmc. It will also need to access search engines and registry services.

Figure 2.7 above depicts how the OSF can be plugged into the workflow Reference Model of the Workflow Management Systems Coaltion. (wfmc). This is currently not part of the OSF but supported by ISO 19119.

A.3

Interface classification scheme

Here service type is identified by a set of operations and the signature(eg input, outputs, exceptions) of each operation in the interface. Services specialise one another through extension or restriction of their interfaces, the operations of the interfaces and the signature of individual operations. Services organised according to this scheme can provide partial basis for service chaining. “An interface inheritance scheme is under development in the OGC interoperability program” [1].

Capability classification scheme

This scheme goes by kind of content they operate on (eg features, coverages, pictures) by content categories eg addresses, streets, parcels etc. Also by other metadata such as descriptions of the service provider, region of validity, temporal range (epoch) of validity, types of data content, sources of content, quality of service. This scheme defines the service type. “A capability classification scheme is under development in the OGC Interoperability program”[1]. This information is available by invoking the operation “Get Capabilities” on the Basic Registry Interface.

Appendix B - Fisheries Usecase – More Details

Figure B.1 Interactions of Computational Objects – Fisheries Use case _ UML Sequence Diagram

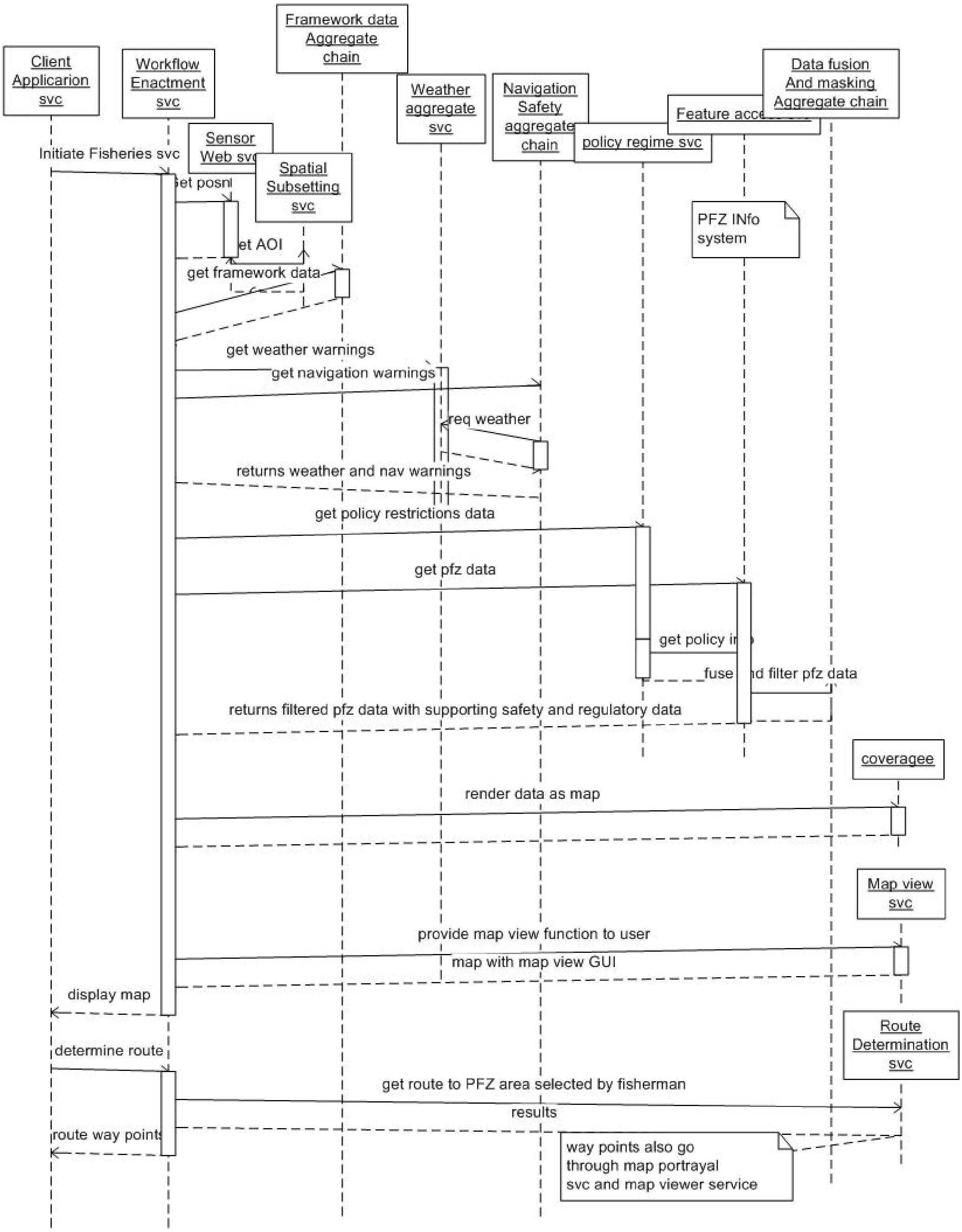


Table B.1 Information Objects

Process Step	Inputs	Outputs	Control Info	Resources
Log On	Username, password			
Validate	Username, password	Service Status	Vessel registration no.	Fishing vessel database
Input Parameters	Radius of operation			
Validate Parameters	Radius of operation	Accept/reject input information		
Get Users GPS posn	Accept/reject input information			Users GPS sensor information
Get AOI	Users current position in Latitude, Longitude, Radius of interest	Area of interest	Area of interest must be subset of service coverage	
Get Framework Data	Area of interest	Bathymetry Grid (coverage) Seabed obstructions (features) Fixed Navigation Aids (eg. Light house) Coastline Islands Drying rocks and banks	Accuracy information	Hydrographic framework database
Get Nav Warning	Area of interest	New wrecks Military exercise area with time New shoals depths detected Submarine pipeline or cable line operations Observation buoys adrift	AOI in the area of interest expanded by 25% in all directions	Hydrographic data server - Navigation warning database
Get weather warning	Area of interest	Cloud image Wind vector Significant wave ht Currents Storm warnings Storm track	Area of interest is to be expanded by 100% in all directions	Weather database of National Weather service
Get PFZ info	Area of interest	Potential Fishing Zone with depth (of fish availability)	Area based restriction, fleet based restriction, international maritime boundaries regime	Based on PFZ feature database
Get restriction areas	Area of interest	Limits of restriction areas for eg. marine parks, mangroves, marine archaeological science, high pollution areas	Restriction policies	Fisheries restriction areas coverage database
Get Maritime Boundaries	AOI	International maritime boundaries with neighbours Line defining Exclusive	Maritime boundaries agreements	Maritime boundaries database

Process Step	Inputs	Outputs	Control Info	Resources
		Economic Zone		
Align SRS	Datum/projection transformation parameters	All data layers on single SRS	Reference SRS	
Overlay				
Render Map	AOI			
View Map	User selected bounding box	Map on WGS 84 datum		
Determine Route	Current position, target position	Set of waypoints including start and end points		
Overlay on Map				
Refresh Map for Route				