NAVI Programme

NAVImap

A Standards-Compliant Spatial Data and Map Service

Final Report

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Executive Summary

NAVImap is a test data service, developed in the NAVI Programme, serving maps and geospatial data utilizing internationally accepted standardized technologies. The most essential standards implemented in the service are the Web Map Service (WMS) and Web Feature Service (WFS) specifications of the Open GIS Consortium (OGC). The data encoding conforms to the OGC's Geography Markup Language (GML) specification and to the World Wide Web Consortiums vector graphics format Scalable Vector Graphics (SVG). The service has been build by the Finnish Geodetic Institute (FGI).

The NAVImap test service can be divided into following main components:

- XML Schema based data modeling of the dataset to be provided in the service as a GML 2.0 compliant Application Schema
- A vector database supported data service conforming to the GML 2.0 specification
- An access interface implementing the Web Feature Service specification and serving the above mentioned dataset
- An access interface conforming to the Web Map Service specification and serving map information as an SVG image
- A traditional raster image (PNG, JPEG) based map service of the same dataset

The NAVImap project was started at the FGI in the beginning of the October 2001. The datasets for the service were provided by the Finnish Digiroad initiative, the National Land Survey of Finland and the City of Helsinki. The spatial coverage of the service concentrated around three major Finnish cities: Helsinki, Tampere and Turku.

The NAVImap service became online at the beginning of the year 2002. The access to the service was restricted to the members of the NAVI Programme only. In total, 25 organizations of the NAVI network registered as NAVImap users and made altogether about 3500 individual visits to the service during the year 2002.

Tiivistelmä

NAVImap on NAVI-ohjelman testiympäristöön kuuluva kansainvälisiä standardeja noudattava kartta- ja paikkatietopalvelu. Keskeisiä standardeja palvelussa ovat Open GIS konsortion (OGC) Web-ympäristöön kehitetyt rajapintaspesifikaatiot Web Map Service (WMS) ja Web Feature Service (WFS) sekä paikkatietojen XML-pohjainen koodausstandardi Geography Markup Language (GML), sekä World Wide Web konsortion (W3C) XML-vektorigrafiikkastandardi Scalable Vector Graphics (SVG). Palvelun on toteuttanut Geodeettinen laitos.

Projektissa toteutettu palvelukokonaisuus voidaan jakaa seuraaviin komponentteihin:

- tarjottavan aineiston XML Schema -pohjainen tietomallinnus GML 2.0 spesifikaation pohjalta toteutettavana sovellustason tietomallina (Application Schema)
- aineiston GML 2.0 -yhteensopivan tietokantapohjaisen tietopalvelun rakentaminen
- edellä mainitun tiedon kyselyrajapinnan toteuttaminen Web Feature Service -määrittelyä noudattavana palveluna
- samaan aineistoon pohjautuva Web Map Service -rajapintaa noudattava palvelu, joka tarjoaa tuloksena syntyvän kartan SVG-kuvana ja
- rasterimuotoisena esityksenä (PNG- ja JPEG kuvana)

NAVImap projekti aloitettiin Geodeettisessa laitoksessa lokakuun alussa vuonna 2001. Aineistoja palveluun luovuttivat Digiroad hanke, Maanmittauslaitos ja Helsingin kaupunki. Alueellisesti palvelun aineistot keskittyivät Helsingin, Tampereen ja Turun ympäristöön.

NAVImap palvelu avattiin vuoden 2002 alussa. Pääsy palveluun annettiin vain NAVI ohjelman jäsenorganisaatioille. Yhteensä 25 NAVI verkoston organisaatiota rekisteröityi palvelun käyttäjäksi. Palveluun tehtiin yhteensä noin 3500 yksittäistä vierailua vuoden 2002 aikana.

Contents

1 Introduction

The display of map data on mobile devices is currently under focus, especially because of the recent activity around the concept of Location Based Services (LBS). Many useful location-aware services can be built without map display on the mobile terminal and some service categories can be realized even completely without access to spatial data resources. However, in some service types a significant improvement can be achieved in the usability if map data can be utilized. Map displays are useful, for instance, in various guidance and navigation services. A fundamental design principle for this kind of service is that map display must be brought to the terminal via a wireless network connection on the moment the service is accessed. A service architecture based on pre-loaded map data does not seem appropriate in the context of dynamic mobile services.

Mobile use of network based map services poses some new challenges for the service providers. Firstly, the map display can, and should, be made context-sensitive and adaptable to the actual usage situation. Once location determination methods get accurate enough, even the position of the user might be taken into account. For this kind of service scenario to be feasible, map services cannot rely on pre-designed, generic, fit-for-all maps. Instead, mobile maps have to be tailored in real-time to adapt them into the needs and preferences of the user. Secondly, mobile maps will be specifically used while moving in an unfamiliar environment. This fact puts high demand on the portability of the service – it's nice to check one's location using a mobile map while on way from home to office, but much more so when traveling in a foreign country. Use of standardized service interfaces is a key requirement to make flexible service roaming feasible.

The limited computing facilities available in current mobile devices sets significant limitations for the map display. The processing power of the terminals can be assumed to be constantly increasing, but on the other hand in the future even smaller devices will probably be introduced. As a consequence, limited capacity terminals will be also used in the future. This kind of devices can typically display map data only as raster images or in the form of textual or audible information. An example of the latter would be a navigation service based on audible turning-point instructions. However, the use of vector-formatted map displays on mobile devices is an interesting topic to be investigated, because of the advantages it brings to the application. These advantages include better local interactivity, better support for personalized, ad hoc maps, good linking and animation support etc.

In mobile services up-to-date information is vital. Access to current data, independently of the time of the day or location of the user, is a fundamental requirement in these services. The first operative mobile services are specifically

designed for checking the current value of the subject in question, examples ranging from stock prices to news feeds to bank accounts. When developing location based services, the same demand for up-to-date information naturally also concerns map data. This demand is especially important in the case of road information used in operative car navigation services. If the introduced roadblock does not instantly show up in the road database, the usefulness of the navigation service is questionable.

As a part of the activities of the NAVI Programme, a testing environment is being set up to foster a common approach to certain essential protocols and interfaces in the service architecture for personal navigation in the national level. The Finnish Geodetic Institute successfully proposed to develop a spatial data and map service, NAVImap, to be used inside the NAVI Programme in tests related to various location-aware services that support personal navigation. The main idea presented in the proposal is to apply available international standards as widely as possible in the service to be built.

The main goals of the NAVImap project might be summarized as responses to above raised points. The need to provide up-to-date maps to the mobile user necessitates the provision of network based map services that can be accessed using over-the-air interfaces. By supporting fundamental Web technologies, like http-protocol, XML-encoding (GML, SVG, XHTML) and common Web image formats (JPEG, PNG), the NAVImap service is easily reachable from the Mobile Internet platform. The idea in NAVImap service is to retrieve data from a maintained geospatial database on the moment the request is made. Use of vector-formatted map information in the service provides an opportunity for various developers to test the emerging XML-based vector graphics encodings in their client applications. Finally, the adherence to the standardized access interfaces improves the usability and portability of the NAVImap service.

2 Service Architecture

The open system architecture of an on-line map service might be based on a layered service stack, in which a service would make queries to the service below it, do some processing on the data received as a response, and provide the results of this process as a service to the service layer above it. The level of detail in specifying the layers is a matter of discussion, but if the services were to be run on separate computers communicating through network, too fine-grained service definition would create a significant disadvantage in terms of overall system performance.

For the above-mentioned reason a four level system architecture can be envisaged (Figure 1). In the first level the data providers (e.g. National Mapping Agencies, NMA) would run a Spatial Data Service providing raw spatial data in an XML –encoded form. Above the data services is the Application Service layer. The responsibilities of this layer include for instance coordinate transformations and other data processing

procedures, like schema transformations. Also integration with other information services is a significant task that might be carried out on Application layer.

The third layer in the system architecture could be called Portal Service. The main responsibilities of this layer can be listed as: provide basic metadata service to the client, process the service requests coming from the client forwarding the request in an appropriate form to the Application Service layer below, and transform the resulting piece of geospatial data into an visual representation, according to the capabilities of the client platform in question.

On the fourth layer are finally the client applications. An advantage of the layered architecture approach is that the results can be adapted to a wide set of different client environments. For example the following three client platforms could be considered: the traditional Web browsing on a PC platform, Personal Java based clients on PDA devices, Java MIDP (Mobile Information Device Profile) clients on mobile phones.

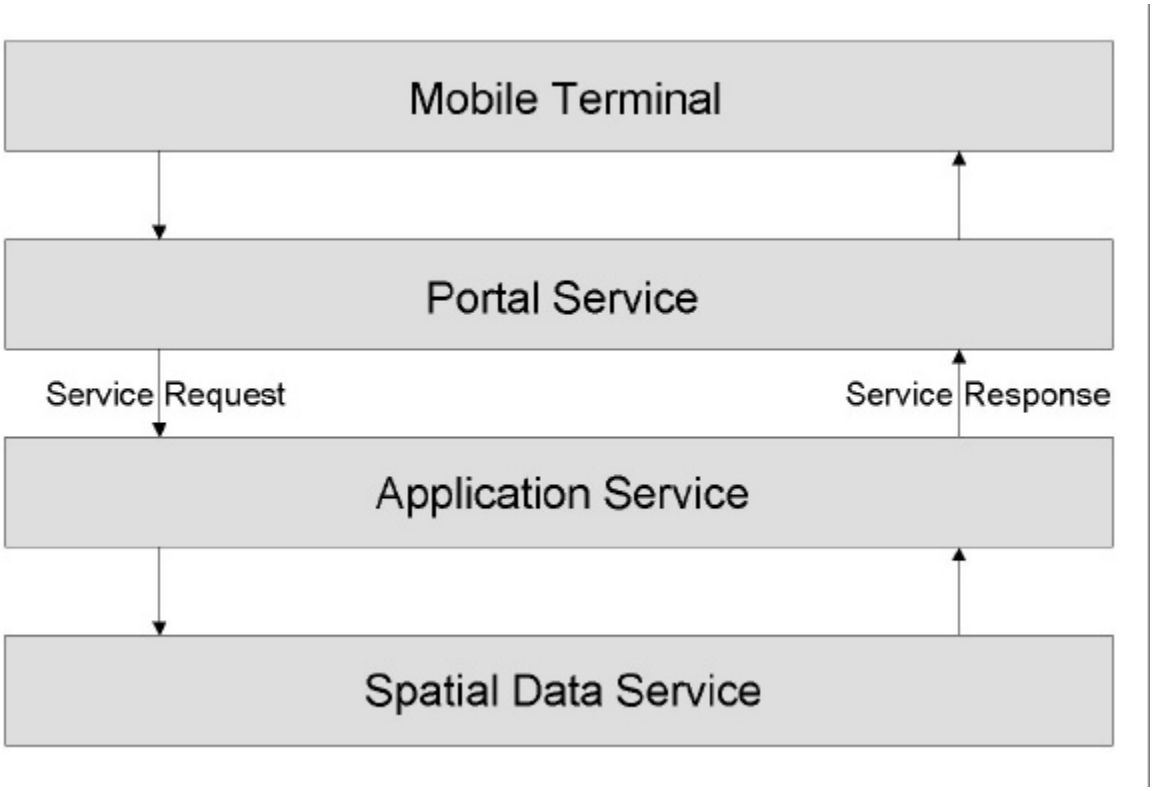

Figure 1. Four-level service architecture for mobile map services

The communication from layer to layer must be based on internationally accepted interface standards. At the moment the main interface specifications that can be considered in the architecture include Web Feature Service (WFS) specification of the OGC as the access interface in the Spatial Data Service layer, Web Map Service

(WMS) specification of the OGC as the query interface of the Portal Layer, and Presentation Service of the Open Location Services (OpenLS) initiative as an alternative access interface on the Portal Layer.

3 Applied Standards

Most of the existing Web and mobile map services are currently based on proprietary access interfaces and data formats. This situation largely exists due to the protective measures taken by individual service providers or software vendors in order to defend the achieved position in the market place. Extensive specifications applicable to the on-line processing of geospatial data have also been virtually non-existent. Recently the situation has changed significantly, however. Now that first standardized interface specifications have been developed, the traditionally isolated spatial software vendors and service providers start seeing mutual benefits in supporting those specifications.

The data transfer mechanisms employed in the networked environment are increasingly based on the Extensible Markup Language technologies (XML). The Open GIS Consortium (OGC) has also defined an XML application for spatial data. This specification is called Geography Markup Language (GML). Many GIS software vendors are currently developing support for this new data encoding mechanism into their products. The use of XML technology allows for structured encoding and device-independent presentation of spatial data.

OGC has also developed a map query interface specification, called Web Map Service (WMS). A WMS-compliant map service provides map data for its client applications in the form of an image. Independently of the applied internal data management solutions, a WMS-service always delivers a raster or vector map image as a response to the query message it receives. An ongoing process in the OGC, the Open Location Services (OpenLS) initiative, is currently developing a map query interface definition, called Presentation Service, specifically targeted for limited-capacity terminals.

Web Feature Service (WFS) specification has been recently adopted by the OGC. A WFS-conformant service provides the client applications with real spatial data, geospatial Features in OGC's terminology, not with pre-visualized map images like a WMS-service. The resulting spatial dataset is expressed in the form of a GML-encoded dataset.

Scalable Vector Graphics (SVG) is a standard for Web vector graphics developed by the World Wide Web Consortium (W3C). Being an XML application SVG constitutes an open, vendor-neutral and powerful vector graphics language that can easily be integrated with other XML-encoded datasets during the service processing.

4 Service Components

The main functional components in the NAVImap service can be listed as follows. 1. Provision of the XML Schema-based data model, as a GML 2.0 Application Schema, for the spatial datasets being introduced to the service, 2. Live connection to a database containing the selected datasets and provision of a GML 2.0 -compliant data service from that database, 3. A minimal server implementation of the OGC's Web Feature Service specification (Basic WFS), providing access to the datasets in the database, 4. A server implementation consistent with the OGC's Web Map Service interface specification, serving the same datasets in visual form, 5. The resulting map displays provided in the form of an SVG vector image, 6. For limited capacity devices the same displays available also as PNG and JPEG raster images. In the following each of these components is discussed in some detail.

4.1 XML Schema-based Data Model as a GML Application Schema

The GML specification states a set of rules about how local Application Schemas are to be derived form the GML base constructs using the inheritance mechanism present in the XML Schema. This kind of data model has been designed for the datasets selected into the NAVImap service. The data model contains of a two-level container hierarchy (FeatureCollection), in which the outmost element is called NAVImap. On the second level of the hierarchy there is a container element for each of the organizations providing data for the service (currently NAVIdigiroad, NAVInls, NAVIhelsinki). Under these FeatureCollections are the real GML Features (9 different Feature types) The NAVImap Schema is presented as an Appendix A of this document.

The XML Schema document is read into a DOM structure when the service is started up. When a request is received through the DescribeFeatureType –interface of the WFS, an appropriate part of the schema is retrieved and returned by carrying out a proper XSLT transformation on the document. The XML tools employed in the NAVImap include free software products from Apache.org, like Xerces XML Parser, Xalan XSLT Processor and Batik SVG library. The Servlet Engine by which the services are run is a product called Tomcat, and as a Web server the ubiquitous Apache server is used (see Figure 2). The operating system platform is Linux.

4.2 An Online Geospatial Database

The NAVImap service is based on free software components. As a database system, PostgreSQL relational database with its PostGIS spatial extension is used. Communication from the WFS implementation to the database is established via a JDBC driver. PostGIS stores spatial data in the database in a way compliant with the OGC's Simple Features specification. Spatial indexing is supported by an R-Tree-derived mechanism called Generalized Search Tree (GiST).

4.3 An Implementation of the WFS Specification

In the case of the NAVImap service, the WFS implementation is based on in-house software development at the FGI, and is coded as a Java Servlet. The NAVImap WFS implementation is a minimal realization of the Basic WFS, i.e. the read-only version of the service. The WFS interfaces supported include GetCapabilities, DescribeFeatureType and GetFeature. Only the simplest form of the GetFeature spatial query constraint, a rectangle, is supported. Property constraints can be set only against a literal value. Complicated logical operations are not supported. The data retrieved from the database is written out as GML constructs. The transformation is simple, because both incoming and outgoing data streams comply with the same data model, namely Simple Features.

4.4 A WMS Implementation

Also the WMS module is a Java Servlet, programmed at the FGI. The server implements the WMS interfaces GetCapabilities and GetMap. Currently there is no support for other coordinate systems than the national Finnish reference systems, YKJ and KKJ. In addition to vector-based datasets stored in the NAVImap database, a raster background map can be requested and is retrieved from the MapSite of the National Land Survey (NLS) during the query processing. Conceptually WMS could be seen as a front-end service that would make use of some WFS resources in the background, but in the case of NAVImap these services are parallel, not sequential. The reason for this setup is the performance gain that can be achieved by accessing the database directly from the WMS, without the help of a WFS server.

4.5 SVG Based Map Display

The NAVImap WMS server allows the resulting map to be encoded as an SVG image. Because of the differences in the data model, the transformation from the internal Simple Features schema into the SVG constructs requires more computing effort than in the case of the GML encoding. The SVG image is created as a flat file in the local hard disc of the server and only a URL address pointing to this file is sent to the requesting client. Streaming SVG code directly from server to the client was also tested, but the approach did not seem to work over low capacity modem lines.

4.6 Raster Image Support

The WMS server also supports map delivery as raster images. In this case the server builds an SVG image from the data received from the database. This image is not written to a disc file, but constructed as a DOM tree. The SVG DOM structure is then

processed by the Batik SVG library to produce the raster image, either in JPEG or PNG format.

In the following illustration the internal schema of the NAVImap service is depicted (Figure 2). The modules shown in orange color represent the parts of the software that have been programmed in the NAVImap project. In addition to Java software, the project outcome includes the GML Application Schema as an XML Schema document (NAVImap.xsd, see Appendix A), the WMS and WFS Capabilities documents as XML files (see Appendix B), map visualization properties as Cascading Style Sheet (CSS) documents and the HTML files constituting the project Web site.

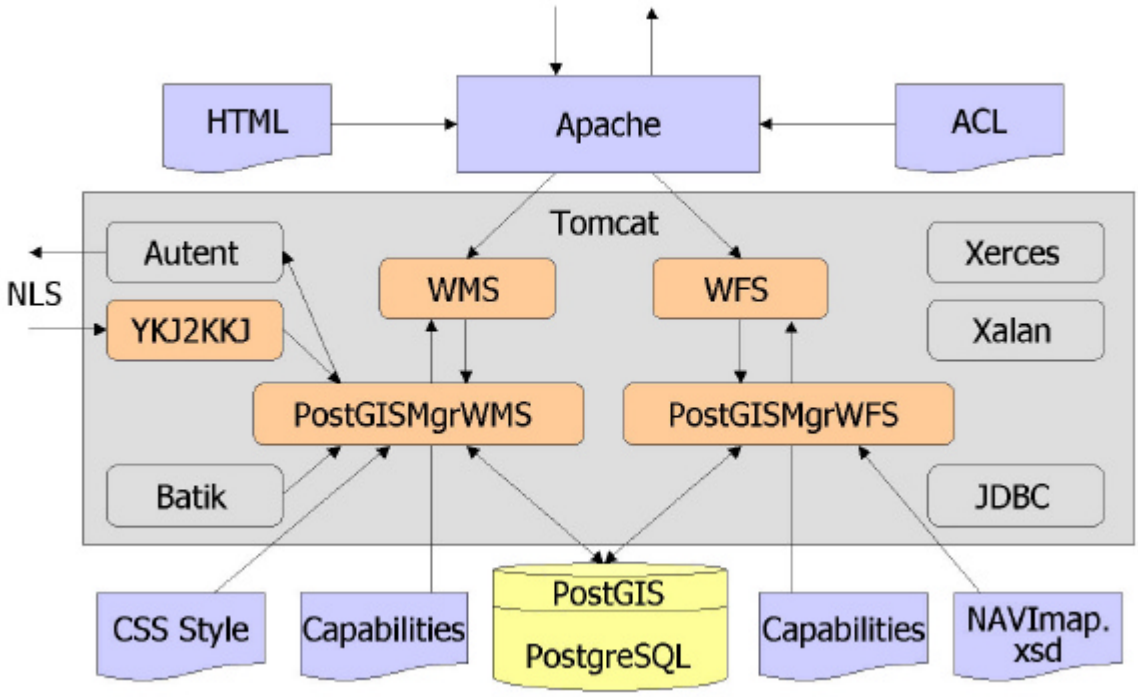

Figure 2. Internal structure of the NAVImap service

The NAVImap service implements interfaces belonging to different service layers in the four-layer architecture presented in chapter 2. The database management system with its spatial extension and the WFS server are clearly part of the Spatial Data Service layer, whereas the WMS map access interface is conceptually part of the Portal Layer. Coordinate transformation module (YKJ2KKJ) can be seen as a component of the Application Service Layer. For practical reasons the WMS and WFS implementations were developed as parallel components in the case of the NAVImap service. To achieve better flexibility, these services should be constructed in a sequential manner and be connected to each other as a service chain (the WMS server consuming the output of the WFS server).

5 Conclusion

The NAVImap project was started at the FGI in the beginning of the October 2001. The datasets for the service were provided by the Finnish Digiroad initiative, the National Land Survey of Finland and the City of Helsinki. Altogether, 9 different Feature types were included (see Appendix A). The spatial coverage of the service concentrated around three major Finnish cities: Helsinki, Tampere and Turku.

The NAVImap service became online at the beginning of the year 2002. The access to the service was restricted to the members of the NAVI Programme only. The response from the NAVI membership has been encouraging. Various member organizations of the NAVI network have shown a genuine interest in making use of the service to learn about and experiment with the applied standards. In total, 25 organizations registered as NAVImap users and made altogether about 3500 individual visits to the service during the year 2002.

As the general network infrastructure is gradually evolving to support the delivery of graphic information over the air interface to a mobile device, and the capacity of the high-end mobile terminals is to soon enable vector based processing of map data, the introduction of the NAVImap –like test service can be seen as timely indeed. Together with the two other NAVI test platform services - NAVItest providing location information through the access interface compliant with the Location Interoperability Forum (LIF) specifications, and NAVIsearch serving business locations via the Directory Service interface defined by the Open Location Services (OpenLS) initiative of the OGC - the NAVImap service forms an interesting testing environment for various location-aware applications.

References

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GML, Geography Markup Language. http://www.opengis.net/gml/02-069/GML2-12.html

Helsinki, Web Site of the City Survey Division of Helsinki. http://www.kv.hel.fi/kaupunkimittaus/

NAVI Programme, Web Site of the Finnish NAVI Programme. http://www.navi-ohjelma.fi/

NAVImap, Web Site of the NAVImap Service. http://navi.fgi.fi

NAVIsearch, Web Site of the NAVIsearch Service. http://proxnet.vtt.fi/navi/search/

NAVItestbed, Web Site of the NAVItestped Service. http://www.vtt.fi/aut/kau/projects/navitest/

NLS, Web Site of the National Land Survey of Finland. http://www.maanmittauslaitos.fi

OGC, Open GIS Consortium home page. http://www.opengis.org

OpenLS, Open Location Services, home page. http://www.openls.org

PostGIS, Spatial Extension to PostgreSQL Database. http://postgis.refractions.net/

PostgreSQL, Relational Database Management System. http://www.postgresql.org/

SVG, Scalable Vector Graphics. http://www.w3.org/TR/SVG/

SVG Mobile, Mobile SVG Profiles: SVG Tiny and SVG Basic. http://www.w3.org/TR/2003/REC-SVGMobile-20030114/

Tomcat, Java Servlet Engine. http://jakarta.apache.org/tomcat/

W3C, Home Site of the World Wide Web Consortium. http://www.w3.org

WFS, Web Feature Service. http://www.opengis.org/techno/specs/02-058.pdf

WMS, Web Map Service, version 1.1.1. http://www.opengis.org/techno/specs/01-068r3.pdf

Xalan, XSLT Processor Xalan-Java. http://xml.apache.org/xalan-j/

Xerces, XML Parser. http://xml.apache.org/xerces-2j/

XHTML, Extensible HyperText Markup Language. http://www.w3.org/TR/xhtml1/

XML, Extensible Markup Language, http://www.w3.org/XML/

XML Schema, XML Schema Specification. http://www.w3.org/XML/Schema

XSLT, 1999. Extensible Stylesheet Language Transformations. http://www.w3.org/TR/xslt

Appendix A

NAVImap.xsd

```
<?xml version="1.0" encoding="iso-8859-1"?>
<xsd:schema targetNamespace="http://www.fgi.fi/NAVI" xmlns:xsd="http://www.w3.org/2001/XMLSchema"
xmlns:gml="http://www.opengis.net/gml" xmlns:fgi="http://www.fgi.fi/NAVI" elementFormDefault="qualified">
    <xsd:import namespace="http://www.opengis.net/gml" schemaLocation="http://navi.fgi.fi/xsd/feature.xsd"/>
    <xsd:element name="_NAVImapFeatureCollection" type="gml:AbstractFeatureCollectionType" abstract="true"
substitutionGroup="gml:_FeatureCollection"/>
    <xsd:element name="_DigiRoadFeature" type="gml:AbstractFeatureType" abstract="true"
substitutionGroup="gml:_Feature"/>
    <xsd:element name="_NLSFeature" type="gml:AbstractFeatureType" abstract="true" substitutionGroup="gml:_Feature"/>
    <xsd:element name="_HelsinkiFeature" type="gml:AbstractFeatureType" abstract="true"
substitutionGroup="gml:_Feature"/>
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maxOccurs="unbounded"/>
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    <xsd:complexType name="NLSAbstractFeatureBaseType" abstract="true">
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                    <xsd:element name="nimi02" minOccurs="0">
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                                <xsd:enumeration value="7"/>
                                <xsd:enumeration value="8"/>
                                <xsd:enumeration value="9"/>
                                <xsd:enumeration value="99"/>
                            </xsd:restriction>
                        </xsd:simpleType>
                    </xsd:element>
                    <xsd:element name="leveys" type="xsd:unsignedShort" minOccurs="0"/>
                    <xsd:element name="nopeusrajoitus" type="xsd:unsignedShort" minOccurs="0"/>
                    <xsd:element name="keskiviiva" type="gml:LineStringPropertyType" minOccurs="0"/>
                </xsd:sequence>
            </xsd:extension>
        </xsd:complexContent>
    </xsd:complexType>
</xsd:element>
<xsd:element name="Pysäkki" substitutionGroup="fgi:_DigiRoadFeature">
    <xsd:complexType>
        <xsd:complexContent>
            <xsd:extension base="gml:AbstractFeatureType">
                <xsd:sequence>
                    <xsd:element name="numero" type="xsd:integer" minOccurs="0"/>
                    <xsd:element name="nimi" type="xsd:string" minOccurs="0"/>
                    <xsd:element name="sijainti" type="gml:PointPropertyType" minOccurs="0"/>
                </xsd:sequence>
            </xsd:extension>
        </xsd:complexContent>
    </xsd:complexType>
</xsd:element>
<xsd:element name="Pelto" substitutionGroup="fgi:_NLSFeature">
    <xsd:complexType>
        <xsd:complexContent>
            <xsd:extension base="fgi:NLSAbstractFeatureBaseType">
                <xsd:sequence>
                    <xsd:element name="reuna" type="gml:PolygonPropertyType" minOccurs="0"/>
                </xsd:sequence>
            </xsd:extension>
        </xsd:complexContent>
    </xsd:complexType>
```

```
    </xsd:element>
    <xsd:element name="Oja" substitutionGroup="fgi:_NLSFeature">
        <xsd:complexType>
            <xsd:complexContent>
                <xsd:extension base="fgi:NLSAbstractFeatureBaseType">
                    <xsd:sequence>
                        <xsd:element name="pohja" type="gml:LineStringPropertyType" minOccurs="0"/>
                    </xsd:sequence>
                </xsd:extension>
            </xsd:complexContent>
        </xsd:complexType>
    </xsd:element>
    <xsd:element name="Joki" substitutionGroup="fgi:_NLSFeature">
        <xsd:complexType>
            <xsd:complexContent>
                <xsd:extension base="fgi:NLSAbstractFeatureBaseType">
                    <xsd:sequence>
                        <xsd:element name="reuna" type="gml:PolygonPropertyType" minOccurs="0"/>
                    </xsd:sequence>
                </xsd:extension>
            </xsd:complexContent>
        </xsd:complexType>
    </xsd:element>
    <xsd:element name="Rautatie" substitutionGroup="fgi:_NLSFeature">
        <xsd:complexType>
            <xsd:complexContent>
                <xsd:extension base="fgi:NLSAbstractFeatureBaseType">
                    <xsd:sequence>
                        <xsd:element name="keskilinja" type="gml:LineStringPropertyType" minOccurs="0"/>
                    </xsd:sequence>
                </xsd:extension>
            </xsd:complexContent>
        </xsd:complexType>
    </xsd:element>
    <xsd:element name="Rautatieasema" substitutionGroup="fgi:_NLSFeature">
        <xsd:complexType>
            <xsd:complexContent>
                <xsd:extension base="fgi:NLSAbstractFeatureBaseType">
                    <xsd:sequence>
                        <xsd:element name="sijainti" type="gml:PointPropertyType" minOccurs="0"/>
                    </xsd:sequence>
                </xsd:extension>
            </xsd:complexContent>
        </xsd:complexType>
    </xsd:element>
    <xsd:element name="Paikannimi" substitutionGroup="fgi:_NLSFeature">
        <xsd:complexType>
            <xsd:complexContent>
                <xsd:extension base="fgi:NLSAbstractFeatureBaseType">
                    <xsd:sequence>
                        <xsd:element name="teksti" type="xsd:string" minOccurs="0"/>
                        <xsd:element name="sijainti" type="gml:PointPropertyType" minOccurs="0"/>
                    </xsd:sequence>
                </xsd:extension>
            </xsd:complexContent>
        </xsd:complexType>
    </xsd:element>
    <xsd:element name="Rakennus" substitutionGroup="fgi:_HelsinkiFeature">
        <xsd:complexType>
            <xsd:complexContent>
                <xsd:extension base="fgi:NLSAbstractFeatureBaseType">
                    <xsd:sequence>
                        <xsd:element name="seinalinja" type="gml:PolygonPropertyType" minOccurs="0"/>
                    </xsd:sequence>
                </xsd:extension>
            </xsd:complexContent>
        </xsd:complexType>
    </xsd:element>
</xsd:schema>
```

Appendix B

Gapabilities.xml (WMS)

```
<?xml version="1.0" encoding="iso-8859-1" standalone="no"?>
<!DOCTYPE WMT_MS_Capabilities SYSTEM "http://navi.fgi.fi/dtd/WMS_Capabilities.dtd">
<WMT_MS_Capabilities version="1.1.0" updateSequence="0">
    <Service>
        <Name>WebMapServer</Name>
        <Title>NAVI-ohjelman WMS-karttapalvelu</Title>
        <Abstract>NAVI-testiympäristöön kuuluva WMS-karttapalvelu, jota ylläpitää Geodeettinen laitos. Palvelussa on tarjolla
mm. DigiRoad-aineistoa ja Maanmittauslaitoksen Maastotietokannan aineistoa Helsingin, Tampereen ja Turun
alueelta.</Abstract>
        <KeywordList>
            <Keyword>DigiRoad</Keyword>
            <Keyword>Maastotietokanta</Keyword>
        </KeywordList>
        <OnlineResource xmlns:xlink="http://www.w3.org/1999/xlink" xlink:type="simple" xlink:href="http://navi.fgi.fi"/>
        <ContactInformation>
            <ContactPersonPrimary>
                <ContactPerson>Lassi Lehto</ContactPerson>
                <ContactOrganization>Geodeettinen laitos</ContactOrganization>
            </ContactPersonPrimary>
            <ContactPosition>Tutkija</ContactPosition>
            <ContactAddress>
                <AddressType>postiosoite</AddressType>
                <Address>PL 15</Address>
                <City>Masala</City>
                <StateOrProvince>Masala</StateOrProvince>
                <PostCode>02431</PostCode>
                <Country>Finland</Country>
            </ContactAddress>
            <ContactVoiceTelephone>09 29555210</ContactVoiceTelephone>
            <ContactFacsimileTelephone>09 29555200</ContactFacsimileTelephone>
            <ContactElectronicMailAddress>Lassi.Lehto@fgi.fi</ContactElectronicMailAddress>
        </ContactInformation>
        <Fees>Ei maksuja</Fees>
        <AccessConstraints>Aineistot on tarkoitettu vain NAVI-verkoston sisäiseen käyttöön, palvelun rajapintojen teknistä
testaamista varten. Aineistojen hyödyntäminen muulla tavoin, edelleenjalostaminen ja luovuttaminen eteenpäin on
kielletty.</AccessConstraints>
    </Service>
    <Capability>
        <Request>
            <GetCapabilities>
                <Format>application/vnd.ogc.wms_xml</Format>
                <DCPType>
                    <HTTP>
                        <Get>
                            <OnlineResource xmlns:xlink="http://www.w3.org/1999/xlink" xlink:type="simple"
xlink:href="http://navi.fgi.fi/map/WMS"/>
                        </Get>
                    </HTTP>
                </DCPType>
            </GetCapabilities>
            <GetMap>
                <Format>image/svg+xml</Format>
                <Format>image/png</Format>
                <Format>image/jpeg</Format>
                <DCPType>
                    <HTTP>
                        <Get>
                            <OnlineResource xmlns:xlink="http://www.w3.org/1999/xlink" xlink:type="simple"
xlink:href="http://navi.fgi.fi/map/WMS"/>
                        </Get>
                    </HTTP>
                </DCPType>
            </GetMap>
```

```
        </Request>
        <Exception>
            <Format>application/vnd.ogc.se_xml</Format>
        </Exception>
        <Layer>
            <Title>NAVImap karttapalvelun aineisto</Title>
            <SRS>EPSG:2393</SRS>
            <Layer>
                <Title>DigiRoad-aineisto</Title>
                <AuthorityURL name="TH">
                    <OnlineResource xmlns:xlink="http://www.w3.org/1999/xlink" xlink:type="simple"
xlink:href="http://www.tiehallinto.fi/tied/2001/digiroad.htm"/>
                </AuthorityURL>
                <Layer>
                    <Name>Tie</Name>
                    <Title>Tieverkko</Title>
                    <LatLonBoundingBox minx="" miny="" maxx="" maxy=""/>
                    <BoundingBox SRS="EPSG:2393" minx="" miny="" maxx="" maxy="" resx="" resy=""/>
                    <Identifier authority="TH"/>
                    <Style>
                        <Name>default</Name>
                        <Title>Perustyyli</Title>
                        <Abstract>Yksinkertainen perustyyli, jossa kuvaustapa on vakio</Abstract>
                        <StyleSheetURL>
                            <Format>text/xsl</Format>
                            <OnlineResource xmlns:xlink="http://www.w3.org/1999/xlink" xlink:type="simple"
xlink:href="http://navi.fgi.fi/xsl/Tie_default.xsl"/>
                        </StyleSheetURL>
                    </Style>
                    <Style>
                        <Name>luokka</Name>
                        <Title>Tieluokka</Title>
                        <Abstract>Yksinkertainen perustyyli, jossa kuvaustapa osoittaa tieluokkaa</Abstract>
                        <StyleSheetURL>
                            <Format>text/xsl</Format>
                            <OnlineResource xmlns:xlink="http://www.w3.org/1999/xlink" xlink:type="simple"
xlink:href="http://navi.fgi.fi/xsl/Tie_luokka.xsl"/>
                        </StyleSheetURL>
                    </Style>
                    <ScaleHint min="2.8" max="14"/>
                </Layer>
                <Layer>
                    <Name>Pysäkki</Name>
                    <Title>Pysäkki</Title>
                    <LatLonBoundingBox minx="" miny="" maxx="" maxy=""/>
                    <BoundingBox SRS="EPSG:2393" minx="" miny="" maxx="" maxy="" resx="" resy=""/>
                    <Identifier authority="TH"/>
                    <Style>
                        <Name>default</Name>
                        <Title>Perustyyli</Title>
                        <Abstract>Yksinkertainen perustyyli, jossa kuvaustapa on vakio</Abstract>
                        <StyleSheetURL>
                            <Format>text/xsl</Format>
                            <OnlineResource xmlns:xlink="http://www.w3.org/1999/xlink" xlink:type="simple"
xlink:href="http://navi.fgi.fi/xsl/Pysäkki_default.xsl"/>
                        </StyleSheetURL>
                    </Style>
                    <ScaleHint min="2.8" max="14"/>
                </Layer>
            </Layer>
            <Layer>
                <Title>Maastotietokanta-aineisto</Title>
                <AuthorityURL name="NLS">
                    <OnlineResource xmlns:xlink="http://www.w3.org/1999/xlink" xlink:type="simple"
xlink:href="http://www.nls.fi/kartta/tuotteet/maastotk.html"/>
                </AuthorityURL>
                <Layer>
                    <Name>Taustakartta</Name>
                    <Title>Taustakartta</Title>
```

```
                    <LatLonBoundingBox minx="" miny="" maxx="" maxy=""/>
                    <BoundingBox SRS="EPSG:2393" minx="" miny="" maxx="" maxy="" resx="" resy=""/>
                    <Identifier authority="NLS"/>
                    <Style>
                        <Name>default</Name>
                        <Title>Vakiotyyli</Title>
                        <Abstract>Kartan kuvaustyyli sellaisena kuin se MML:n Karttapaikalta tulee</Abstract>
                    </Style>
                    <ScaleHint min="2.8" max="14"/>
                </Layer>
                <Layer>
                    <Name>Pelto</Name>
                    <Title>Pelto</Title>
                    <LatLonBoundingBox minx="" miny="" maxx="" maxy=""/>
                    <BoundingBox SRS="EPSG:2393" minx="" miny="" maxx="" maxy="" resx="" resy=""/>
                    <Identifier authority="NLS"/>
                    <Style>
                        <Name>default</Name>
                        <Title>Perustyyli</Title>
                        <Abstract>Yksinkertainen perustyyli, jossa kuvaustapa on vakio</Abstract>
                        <StyleSheetURL>
                            <Format>text/xsl</Format>
                            <OnlineResource xmlns:xlink="http://www.w3.org/1999/xlink" xlink:type="simple"
xlink:href="http://navi.fgi.fi/xsl/Pelto_default.xsl"/>
                        </StyleSheetURL>
                    </Style>
                    <ScaleHint min="2.8" max="14"/>
                </Layer>
                <Layer>
                    <Name>Oja</Name>
                    <Title>Oja</Title>
                    <LatLonBoundingBox minx="" miny="" maxx="" maxy=""/>
                    <BoundingBox SRS="EPSG:2393" minx="" miny="" maxx="" maxy="" resx="" resy=""/>
                    <Identifier authority="NLS"/>
                    <Style>
                        <Name>default</Name>
                        <Title>Perustyyli</Title>
                        <Abstract>Yksinkertainen perustyyli, jossa kuvaustapa on vakio</Abstract>
                        <StyleSheetURL>
                            <Format>text/xsl</Format>
                            <OnlineResource xmlns:xlink="http://www.w3.org/1999/xlink" xlink:type="simple"
xlink:href="http://navi.fgi.fi/xsl/Oja_default.xsl"/>
                        </StyleSheetURL>
                    </Style>
                    <ScaleHint min="2.8" max="14"/>
                </Layer>
                <Layer>
                    <Name>Joki</Name>
                    <Title>Joki</Title>
                    <LatLonBoundingBox minx="" miny="" maxx="" maxy=""/>
                    <BoundingBox SRS="EPSG:2393" minx="" miny="" maxx="" maxy="" resx="" resy=""/>
                    <Identifier authority="NLS"/>
                    <Style>
                        <Name>default</Name>
                        <Title>Perustyyli</Title>
                        <Abstract>Yksinkertainen perustyyli, jossa kuvaustapa on vakio</Abstract>
                        <StyleSheetURL>
                            <Format>text/xsl</Format>
                            <OnlineResource xmlns:xlink="http://www.w3.org/1999/xlink" xlink:type="simple"
xlink:href="http://navi.fgi.fi/xsl/Joki_default.xsl"/>
                        </StyleSheetURL>
                    </Style>
                    <ScaleHint min="2.8" max="14"/>
                </Layer>
                <Layer>
                    <Name>Rautatie</Name>
                    <Title>Rautatie</Title>
                    <LatLonBoundingBox minx="" miny="" maxx="" maxy=""/>
                    <BoundingBox SRS="EPSG:2393" minx="" miny="" maxx="" maxy="" resx="" resy=""/>
```

```
                    <Identifier authority="NLS"/>
                    <Style>
                        <Name>default</Name>
                        <Title>Perustyyli</Title>
                        <Abstract>Yksinkertainen perustyyli, jossa kuvaustapa on vakio</Abstract>
                        <StyleSheetURL>
                            <Format>text/xsl</Format>
                            <OnlineResource xmlns:xlink="http://www.w3.org/1999/xlink" xlink:type="simple"
xlink:href="http://navi.fgi.fi/xsl/Rautatie_default.xsl"/>
                        </StyleSheetURL>
                    </Style>
                    <ScaleHint min="2.8" max="14"/>
                </Layer>
                <Layer>
                    <Name>Rautatieasema</Name>
                    <Title>Rautatieasema</Title>
                    <LatLonBoundingBox minx="" miny="" maxx="" maxy=""/>
                    <BoundingBox SRS="EPSG:2393" minx="" miny="" maxx="" maxy="" resx="" resy=""/>
                    <Identifier authority="NLS"/>
                    <Style>
                        <Name>default</Name>
                        <Title>Perustyyli</Title>
                        <Abstract>Yksinkertainen perustyyli, jossa kuvaustapa on vakio</Abstract>
                        <StyleSheetURL>
                            <Format>text/xsl</Format>
                            <OnlineResource xmlns:xlink="http://www.w3.org/1999/xlink" xlink:type="simple"
xlink:href="http://navi.fgi.fi/xsl/Rautatieasema_default.xsl"/>
                        </StyleSheetURL>
                    </Style>
                    <ScaleHint min="2.8" max="14"/>
                </Layer>
                <Layer>
                    <Name>Paikannimi</Name>
                    <Title>Paikannimi</Title>
                    <LatLonBoundingBox minx="" miny="" maxx="" maxy=""/>
                    <BoundingBox SRS="EPSG:2393" minx="" miny="" maxx="" maxy="" resx="" resy=""/>
                    <Identifier authority="NLS"/>
                    <Style>
                        <Name>default</Name>
                        <Title>Perustyyli</Title>
                        <Abstract>Yksinkertainen perustyyli</Abstract>
                        <StyleSheetURL>
                            <Format>text/xsl</Format>
                            <OnlineResource xmlns:xlink="http://www.w3.org/1999/xlink" xlink:type="simple"
xlink:href="http://navi.fgi.fi/xsl/Paikannimi_default.xsl"/>
                        </StyleSheetURL>
                    </Style>
                    <ScaleHint min="2.8" max="14"/>
                </Layer>
            </Layer>
            <Layer>
                <Title>Helsingin kaupungin aineisto</Title>
                <AuthorityURL name="HK">
                    <OnlineResource xmlns:xlink="http://www.w3.org/1999/xlink" xlink:type="simple"
xlink:href="http://www.kv.hel.fi/cl_house/juuri3.htm"/>
                </AuthorityURL>
                <Layer>
                    <Name>Rakennus</Name>
                    <Title>Rakennus</Title>
                    <LatLonBoundingBox minx="" miny="" maxx="" maxy=""/>
                    <BoundingBox SRS="EPSG:2393" minx="" miny="" maxx="" maxy="" resx="" resy=""/>
                    <Identifier authority="HK"/>
                    <Style>
                        <Name>default</Name>
                        <Title>Perustyyli</Title>
                        <Abstract>Yksinkertainen perustyyli, jossa kuvaustapa on vakio</Abstract>
                        <StyleSheetURL>
                            <Format>text/xsl</Format>
```

```
                                    <OnlineResource xmlns:xlink="http://www.w3.org/1999/xlink" xlink:type="simple"
xlink:href="http://navi.fgi.fi/xsl/Rakennus_default.xsl"/>
                                </StyleSheetURL>
                            </Style>
                            <ScaleHint min="2.8" max="14"/>
                        </Layer>
                    </Layer>
                </Layer>
            </Capability>
</WMT_MS_Capabilities>
```

Gapabilities.xml (WFS)

```
<?xml version="1.0" encoding="iso-8859-1" standalone="no"?>
<!DOCTYPE WFS_Capabilities SYSTEM "http://navi.fgi.fi/dtd/WFS_Capabilities.dtd">
<WFS_Capabilities version="0.0.14" updateSequence="0">
    <Service>
        <Name>WebFeatureServer</Name>
        <Title>NAVI-ohjelman WFS-paikkatietopalvelu</Title>
        <Abstract>NAVI-testiympäristöön kuuluva WFS-paikkatietopalvelu, jota ylläpitää Geodeettinen laitos. Palvelussa on tarjolla mm. DigiRoad-aineistoa ja Maanmittauslaitoksen Maastotietokannan aineistoa Helsingin, Tampereen ja Turun alueelta. Lisätietoja: Lassi.Lehto@fgi.fi</Abstract>
        <OnlineResource>http://navi.fgi.fi</OnlineResource>
        <Fees>Ei maksuja</Fees>
        <AccessConstraints>Aineistot on tarkoitettu vain NAVI-verkoston sisäiseen käyttöön, palvelun rajapintojen teknistä testaamista varten. Aineistojen hyödyntäminen muulla tavoin, edelleenjalostaminen ja luovuttaminen eteenpäin on kielletty.</AccessConstraints>
    </Service>
    <Capability>
        <Request>
            <GetCapabilities>
                <DCPType>
                    <HTTP>
                        <Get onlineResource="http://navi.fgi.fi/map/WFS"/>
                    </HTTP>
                </DCPType>
            </GetCapabilities>
            <DescribeFeatureType>
                <SchemaDescriptionLanguage>
                    <XMLSCHEMA/>
                </SchemaDescriptionLanguage>
                <DCPType>
                    <HTTP>
                        <Get onlineResource="http://navi.fgi.fi/map/WFS"/>
                    </HTTP>
                </DCPType>
            </DescribeFeatureType>
            <GetFeature>
                <ResultFormat>
                    <GML2/>
                </ResultFormat>
                <DCPType>
                    <HTTP>
                        <Get onlineResource="http://navi.fgi.fi/map/WFS"/>
                    </HTTP>
                </DCPType>
            </GetFeature>
        </Request>
    </Capability>
    <FeatureTypeList>
        <Operations>
            <Query/>
        </Operations>
        <FeatureType>
            <Name>NAVImap</Name>
            <SRS>EPSG:2393</SRS>
            <LatLonBoundingBox minx="" miny="" maxx="" maxy=""/>
        </FeatureType>
        <FeatureType>
            <Name>NAVIdigiroad</Name>
            <SRS>EPSG:2393</SRS>
            <LatLonBoundingBox minx="" miny="" maxx="" maxy=""/>
        </FeatureType>
        <FeatureType>
            <Name>NAVInls</Name>
            <SRS>EPSG:2393</SRS>
```

```
            <LatLonBoundingBox minx="" miny="" maxx="" maxy=""/>
        </FeatureType>
        <FeatureType>
            <Name>NAVIhelsinki</Name>
            <SRS>EPSG:2393</SRS>
            <LatLonBoundingBox minx="" miny="" maxx="" maxy=""/>
        </FeatureType>
        <FeatureType>
            <Name>Tie</Name>
            <SRS>EPSG:2393</SRS>
            <LatLonBoundingBox minx="" miny="" maxx="" maxy=""/>
        </FeatureType>
        <FeatureType>
            <Name>Pysäkki</Name>
            <SRS>EPSG:2393</SRS>
            <LatLonBoundingBox minx="" miny="" maxx="" maxy=""/>
        </FeatureType>
        <FeatureType>
            <Name>Pelto</Name>
            <SRS>EPSG:2393</SRS>
            <LatLonBoundingBox minx="" miny="" maxx="" maxy=""/>
        </FeatureType>
        <FeatureType>
            <Name>Oja</Name>
            <SRS>EPSG:2393</SRS>
            <LatLonBoundingBox minx="" miny="" maxx="" maxy=""/>
        </FeatureType>
        <FeatureType>
            <Name>Joki</Name>
            <SRS>EPSG:2393</SRS>
            <LatLonBoundingBox minx="" miny="" maxx="" maxy=""/>
        </FeatureType>
        <FeatureType>
            <Name>Rautatie</Name>
            <SRS>EPSG:2393</SRS>
            <LatLonBoundingBox minx="" miny="" maxx="" maxy=""/>
        </FeatureType>
        <FeatureType>
            <Name>Rautatieasema</Name>
            <SRS>EPSG:2393</SRS>
            <LatLonBoundingBox minx="" miny="" maxx="" maxy=""/>
        </FeatureType>
        <FeatureType>
            <Name>Paikannimi</Name>
            <SRS>EPSG:2393</SRS>
            <LatLonBoundingBox minx="" miny="" maxx="" maxy=""/>
        </FeatureType>
        <FeatureType>
            <Name>Rakennus</Name>
            <SRS>EPSG:2393</SRS>
            <LatLonBoundingBox minx="" miny="" maxx="" maxy=""/>
        </FeatureType>
    </FeatureTypeList>
</WFS_Capabilities>
```