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IBNEXT – FUTURE NEEDS AND DEVELOPMENT OF THE ICEBREAKER INFORMATION SYSTEM – A PRESTUDY

Finnish Transport Safety Agency

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FOREWORD

In its report no 85, the Winter Navigation Research Board presents the outcome of the project: IBNext – Future needs and development of the icebreaker information system – a prestudy.

In spite of the ice conditions in wintertime, ship transportation is operational all year around in the Baltic Sea. To optimally utilise the icebreakers, efficient coordination of the resources is needed. This requires tools and systems to provide the necessary information. The distributed information system used on board the icebreakers in the Baltic Sea was originally developed in 1990's. Since then the user base has expanded, and advances in communication technology have enabled new feasible solutions to be used as a base for the information system when developing it further. New computers may enable solutions that were unrealistic to utilise 10 years ago. This report describes the results of a prestudy about the future needs and development regarding the successor of the present icebreaker information system IBNet.

The report lists the most important stakeholder and user groups and their needs regarding information about the icebreakers in operation. Useful information coming from external systems is also handled. The technological changes in the environment and systems are briefly handled and finally a roadmap for how to proceed with developing the IBNext system, is suggested.

The Winter Navigation Research Board warmly thanks Mr. Robin Berglund and Mr. Renne Tergujeff and Mr. Teppo Veijonen for this report.

Helsinki and Norrköping

June 2014

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RESEARCH REPORT

VTT-CR-08848-12

IBNext

Future needs and development of the icebreaker information system – a prestudy

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Summary

In spite of the ice conditions in wintertime, ship transportation is operational all year around in the Baltic Sea. To optimally utilise the icebreakers, efficient coordination of the resources is needed. This requires tools and systems to provide the necessary information.

This report describes the results of a prestudy funded by the Winter Navigation Research Board. The prestudy is about the future needs and development regarding the icebreaker information system, i.e. the successor of the present information system IBNet.

The report lists the most important stakeholder and user groups and their needs regarding information about the icebreakers in operation. Useful information coming from external systems for the users on board the icebreakers, is also handled.

The technological changes in the environment and systems are briefly handled.

Finally a roadmap for how to proceed with developing the IBNext system, is suggested.

Confidentiality	Restricted

Espoo, 3 July 2014

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Preface

The distributed information system used on board the icebreakers in the Baltic Sea was originally developed in 1990's. Since then the user base has expanded, and advances in communication technology have possibly enabled new feasible solutions to be used as a base for the information system when developing it further. New and faster computers may enable solutions that were unrealistic to utilise 10 years ago.

This was the starting point for the prestudy funded by the Board of Winter navigation.

The study has been performed by the VTT Technical Research Centre of Finland.

The project Steering group has consisted of Jarkko Toivola, Finnish Traffic Administration; Ulf Gullne / Johny Lindvall, Göran Rudbäck / Ulf Svedberg from the Swedish Maritime Administration; Jorma Kämäräinen, Finnish Transport Safety Agency; and Ville Kotovirta, VTT.

We greatly appreciate the time and effort offered by the persons that have been interviewed: Mikael Renz (IT architect), Rolf Zetterberg (AIS system expert), Per Lundqvist, Mats Kannerståhl (IT experts), Tomas Årnell, Ulf Gullne, Johny Lindvall (icebreaking management), Peter Geite (IT manager), Karl Herlin (master, Atle) and Fredrik Karlsson (new development projects). In Finland we want to thank the following persons: Rami Laaksonen (Archipelago VTS), Mikko Turunen (Gulf of Finland VTS). Christian Wennerstrand (master, ib Kontio) and Simo Haaslahti (First mate, Kontio) have provided valuable ideas on how to develop the system. Mirva Hannukainen has been active in giving us feedback on the use of IBNet from an operator's perspective and suggesting people to meet.

3 July 2014

Authors

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Terms

Term	Description
AIS	Automatic Identification System
DirWay	synonym for Ice Waypoints
ECDIS	Electronic Chart and Display Information System
ENC	Electronic Navigational Chart
ENSI	Enhanced Navigation Support Information, a system developed within the Tanker Safety Project lead by John Nurminen Foundation.
IALA	International Association of Lighthouse Authorities
IBNet	Distributed information system for icebreakers
Ice Waypoints	Route points that an icebreaker issues for ships to follow when navigating at sea (also called Dirways)
IHO	International Hydrographic Organization
IMO	International Maritime Organisation
IRIS	The predecessor of IBNet
LTE	Long-Term Evolution
MRCC	Maritime Rescue Coordination Centre
Node	A local subsystem having a local database which is common for all users in that node. A node may have more than one local user.
VSAT	Very Small Aperture Terminal
VTS	Vessel Traffic Service

1 Introduction

1.1 Icebreaking services in the Baltic Sea

Ship transportation in the Baltic Sea is operational all year around in spite of the ice conditions. This is possible due to icebreakers operated by the states around the Baltic Sea. Also traffic restrictions issued by the authorities guarantee that the ships have the capabilities required when going in ice. The restrictions enforce certain minimum hull strength and machine power for the ships to receive icebreaker assistance when going to a port where the ice conditions cause difficulties for the ships.

As the icebreaking resources are limited, it is very important that vessels would manage to navigate by their own during light ice conditions and not engage an icebreaker that is needed in areas with more severe ice conditions. In light ice conditions, there are often no icebreakers in the area, presenting a safety risk for vessels with poor engine power and hull without ice class to navigate in the fairways of that area.

During the winter season 2011 – 2012 the number of icebreakers operating in the Baltic Sea were as depicted in Figure 1.

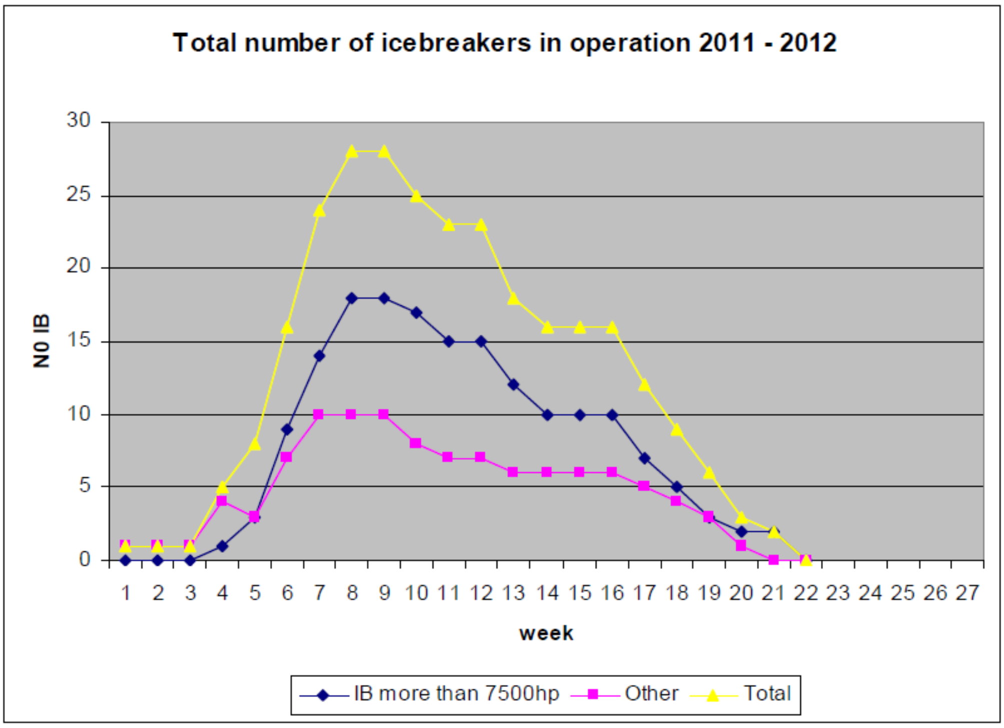

Figure 1. Number of icebreakers in the Baltic Sea 2011 – 2012. [BIM Annual report]

1.2 IBNet – Operational decision support system for icebreaking

Presently, icebreaking operations in the Baltic Sea are supported by IBNet, an operational decision support system which is used by the Finnish, Swedish and Estonian icebreakers.

The first version of the IBNet system was designed in 1996. Since then it has been enhanced and updated yearly, the most important milestones being the addition of IBPlott in 2000 and integration with the real-time AIS information in 2004. The current system represents state-of-the-art in operational decision support systems for winter navigation.

IBNet was originally designed with unreliable and slow communication links in mind. To enable autonomous operations on the icebreakers even when the communication link is temporarily not working, it was decided to implement the system in a distributed way. Each icebreaker has its own database, and the information is replicated between the nodes using an asynchronous replication mechanism. **Virhe. Viitteen lähdettä ei löytynyt.** presents the overall architecture of IBNet.

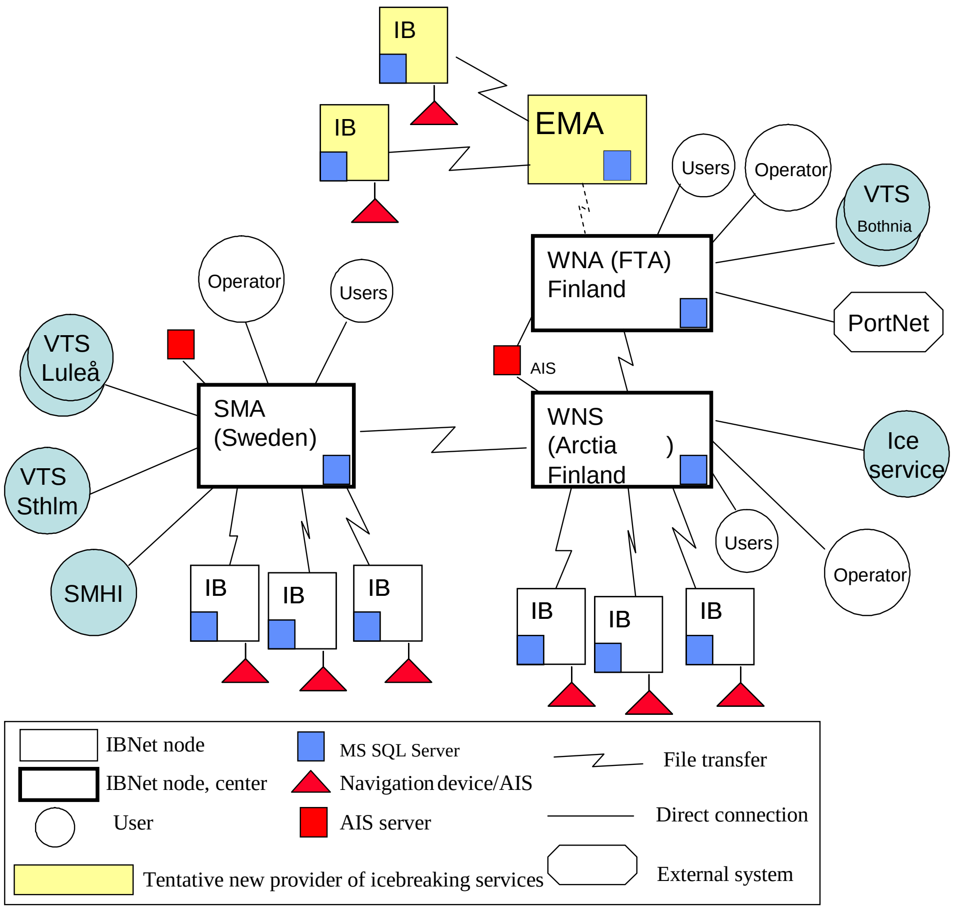

Figure 2. Overall architecture of the IBNet system.

1.3 Change drivers

It has been recognized that the current status and future development of IBNet should be observed in the light of recognized and expected changes in the operational environment, changes in the user needs, as well as the opportunities enabled by advances in technology.

The user base of the system has originally consisted of the icebreaker navigators and masters, as well as winter navigation authorities in Sweden and Finland. Now there is an increasing interest to join the system – both from other authorities in Finland and parties abroad. Estonian icebreakers joined the system in 2011. An expansion of the system to new users should be in line with a strategy roadmap that would have to be agreed upon.

IBNet is being expanded to new users that are directly or indirectly involved in making winter navigation safer and more efficient. The current system architecture and information content may not, however, fully correspond to the requirements that an expanded system should fulfil.

At the same time, advances in telecommunications and in mobile systems design may offer new technical possibilities for the system architecture and implementation possibilities.

1.4 Prestudy: goals and scope

This document presents a prestudy of the future needs and development of the icebreaker information system used on the Baltic Sea. The prestudy aims to support the strategic planning of how to develop the IBNet system further. The document should help the national Winter navigation authorities to make decisions that take into account the changes in both user base and technological development.

The prestudy deals with the requirements, technology identification, vision system, validation and roadmap creation. The study does not deal with business, sustainability and intellectual property rights aspects of the system. These items would be necessary to consider in a scenario where the further development and maintenance would be outsourced to a party outside of the present IBNet consortium.

As a background information, description of IBNet is available as a separate document [R1]. Additionally, the following studies have been conducted previously:

- IBNet architecture review – development possibilities, requirements and scenarios, January 2005 [R2]. This document describes ideas on how to develop IBNet further and the primary data flows in the system as the situation was in 2005.

- Prestudy concerning extension of IBNet to Estonia (2008) [R3]

2 Stakeholder and user identification

Main users of the IBNet system are the icebreaker operators (shipping company operating the icebreakers), icebreaking authorities and the users on board the icebreakers. Stakeholders related to the icebreaking activities are the ship owners, shipping operators, port authorities, oil spill combatting authorities, and VTS operators. Indirectly logistics operators and manufacturing industry are interested in minimising delays and having a good estimate of transport times.

The focus of the IBNet system is on the icebreaking operators and users on board.

Stakeholders	**Overall relevant needs**
Icebreaker operators	Operational tool given by the icebreaking authorities to monitor and guide the service offered by the hired icebreakers.
Icebreaking authorities	Monitoring activities of the icebreakers. Monitor performance of the icebreaking services that has been contracted. Statistical information about how well winter navigation has performed. One important parameter to monitor is the average waiting time of ships when the reason for waiting is that the ship had to wait for icebreaker assistance. Also the number of so called "long waits" is monitored, i.e. number of waits that have been longer than a given limit, usually 4 hours. Information about performance of ships.
Users on board icebreaker (captains and mates)	Situational awareness, i.e. information about the traffic situation, weather and ice conditions for assistance planning. Assistance need estimation. Coordination planning Tactical assistance planning Ship advising. Reporting to the shipping operator and the authorities that have contracted the services.
Ship owners	Indirectly information about the performance of ships in ice conditions
Shipping operators	Monitoring of delays caused by ice conditions.

Port authorities	Logistics planning
VTS operators	Information about icebreaker positions and waypoints to be distributed to the ships that report to them
Logistics operators	Minimising delays. Transport times estimates
Manufacturing industry	Minimising delays Transport times estimates

3 User needs identification

This section presents user requirements that have been gathered from the key user groups.

3.1 Users on board icebreaker / icebreaker operators

3.1.1 Traffic situation

ID	User need	Comment
1.1.1	Current and correct information about the ship traffic, i.e. the position, destination and estimated time of arrivals and departures from port.	
1.1.2	Enter additions/corrections to the ship traffic information (timetable)	When the time table depends on icebreaker availability and ice conditions, icebreakers are the primary source of information.

3.1.2 Assistance need estimation

ID	User need	Comment
1.2.1	Get information about ship capabilities, i.e. ship register data including iceclass	receive, view
1.2.2	Enter comments about ship capabilities, i.e. how the ship behaves when being towed or if it has exceptionally low performance in ice.	manual input on board

1.2.3	Get information about ice and weather conditions	receive, view
1.2.4	Get information about ice and weather forecasts	receive, view

3.1.3 Coordination planning

ID	**User need**	**Comment**
1.3.1	Get information about the intentions and status of other icebreakers	receive, view
1.3.2	Enter information about the intentions and status of own icebreaker	manual input

3.1.4 Tactical assistance planning

ID	**User need**	**Comment**
1.4.1	Get information about ice conditions (ice charts + satellite images)	receive, view
1.4.2	Get information about weather conditions	receive, view
1.4.3	Get ice forecasts (thickness, compression, drift)	receive, view
1.4.4	Get weather forecasts	receive, view
1.4.5	Get water level information and forecasts	receive, view
1.4.6	Enter information about current ice conditions	manual input
1.4.7	Enter weather observations	manual input; can be connected to automatic weather station. Inclusion in IBNet?
1.4.7	Get ship positions (AIS)	receive, view
1.4.8	Enter information about ship positions – in case ship AIS is out of order.	Manual input as a fallback.

3.1.5 Ship advising

ID	**User need**	**Comment**
1.5.1	Get port ice restrictions (valid and planned ice restrictions in different ports)	The restriction are determined by the icebreaking authorities

		(See 2.3.1)
1.5.2	Get information about waypoints	All icebreakers should be aware of the waypoints determined by other icebreakers as well
1.5.3	Enter waypoints	The waypoints are the most important piece of information that are of interest to other ships

3.1.6 Reporting

ID	User need	Comment
1.6.1	Aid in creating icebreaker log book and for reporting fuel consumption etc. The requirement to maintain a so called "kladi" used on the Finnish icebreakers should be possible to satisfy with the information from the IBNext system.	The ship logbook is required by law. Information about assistance distances etc. is more for icebreaker operators to monitor the activities.

3.1.7 Non-functional requirements

ID	User need	Comment
1.7.1	System shall be robust and fast enough.	This is an essential requirement.
1.7.2	The users shall be able to get information and input new information also when the connection from/to the icebreakers is temporarily broken. When the connection is restored, the information shall be synchronised automatically.	
1.7.3	After synchronisation, the information in the different nodes of the system shall be identical except for transients caused by delays in transmission.	
1.7.4	The system should minimise the amount of data to be transferred between the nodes.	The importance of this is dependent on communications capability.

1.7.5	The latency time for transfer of data between the users should be minimised	This is partly a question of adjusting parameters, but also an architecture issue.

3.1.8 Security requirements

ID	**User need**	**Comment**
1.8.1	The system shall ensure that the communication between the nodes is protected and not vulnerable to attacks from the Internet	Although the information as such is not sensitive, it should be protected against malicious attacks.

3.1.9 Improvement ideas from the users

ID	**Idea**	**Comment**
1.9.1	"Planning screen". A large display (42") could be used to display the portlist(s) of ports (1 – 6) that the user can define. The table is fitted to the available window. The list shows ships that arrive/leave within selectable interval (current, 1 or 2 days). Would be used instead of the whiteboard now used on board (at KONTIO at least).	by Simo Haaslahti, ib KONTIO. This could be implemented with present IBBridge application running in a separate computer.
1.9.2	Improved zooming and panning of the IBPlott map.	The user interface should be easy to use and follow best practices for map based applications.
1.9.3	Possibility to choose between ENC map and satellite image	The ENC map as background has not yet been considered necessary, and may even lead the user astray as the satellite image does not have the same spatial resolution.

3.2 Icebreaking authorities

3.2.1 Monitoring the activities of the icebreakers

ID	User need	Comment
2.1.1	The authorities need information about how well the icebreaker resources suffice with respect to the demand, which depends on ice conditions, ship traffic and capabilities of the ships.	
2.1.2	To determine ice restrictions per port, the authorities needs to monitor if the ship capabilities, icebreaking resources and weather (ice) forecasts require changes in the restrictions	
2.1.3	To follow up the obligations of the contracted icebreaking operator, the authorities need a tool to measure how well the operator is able to fulfil its contractual obligations.	

3.2.2 Statistical information

ID	User need	Comment
2.2.1	Statistical information about the performance of the icebreakers is needed partly for the same reason as 2.1.3	how much the icebreakers have assisted, moved etc.
2.2.2	Statistical information about ships that have had to wait for assistance. This is one of the key figures when measuring the overall performance of the icebreaking service.	
2.2.3	Information about performance of ships. This is needed to guide development of iceclass rules and for estimation of icebreaker need.	especially those that have required a lot of assistance resources

3.2.3 Icebreaker operator management

ID	User need	Comment
2.3.1	Dynamic configuration of the roles of the actors in winter navigation	Icebreaker operators may be hired for short terms for certain tasks, and should still be coordinated efficiently.

2.3.2	Determine port ice restrictions (valid and planned ice restrictions in different ports)	Icebreaking management determines port ice restrictions

3.3 VTS operators

The task of the VTS operators is to monitor ship traffic in their area. They also form a contact point for ships approaching the area. In wintertime the VTS operators convey the waypoints through ice to the ships. The VTS operators have their own operational system, and IBNet is relevant only in wintertime. On the other hand, the VTS operators are the contact point to the ships, therefore on-line real time update of the situation between VTS and icebreakers is essential.

The VTS activities are organised differently in Sweden and Finland. In Sweden the tasks are combined with the MRCC (Maritime Rescue Coordination Centre). In Finland there are also plans to merge and reorganise the VTS centres.

ID	**User need**	**Comment**
3.1.1	The VTS operators need to know the current ice waypoints.	
3.1.2	The VTS operators need to inform the icebreakers which points (advice) have been given to which ships.	

3.4 Pilots

ID	**User need**	**Comment**
4.1.1	Pilots need information about icebreaker assistance timing.	Ships on regular routes may have navigating officers with certificates for those fairways, thus not needing external pilots.
4.1.2	Pilots may give a report of the ice conditions along the fairways they have used.	

3.5 System operation and maintenance needs

Every information system has to be operated and maintained. The maintenance activities are installations (new and updates), bug reporting and internal user support. This may be organised differently in different countries. The IT department of the icebreaking authority in respective country may take a large role here, or outsource the tasks completely.

The operational activities are related to adjusting import/export parameters, defining new ports/fixpoints etc.

ID	User need	Comment
5.1.1	The system shall be possible to maintain with a moderate effort.	
5.1.2	The maintenance guide shall allow performing normal maintenance operations without deep knowledge of the system internals.	
5.1.3	Updates/upgrades of installed applications shall be possible to execute as automatic background operations.	
5.1.4	The implementation should be in a computer language/version that is supported and has state-of-the-art development environment for some years to come.	Lifespans of various development technologies are hard to foresee.

4 Advances in relevant technologies and services

4.1 AIS system[1]

The Automatic Identification System (AIS) is an automatic tracking system used on ships and by vessel traffic services (VTS) for identifying and locating vessels by electronically exchanging data with other nearby ships and AIS Base stations. AIS information supplements marine radar, which continues to be the primary information source for collision avoidance in water transport.

Information provided by AIS equipment, such as unique identification, position, course, and speed, can be displayed on a screen or an ECDIS. AIS is intended to assist a vessel's watchstanding officers and allow maritime authorities to track and monitor vessel movements. AIS integrates a standardized VHF transceiver with a positioning system such as a LORAN-C or GPS receiver, with other electronic navigation sensors, such as a gyrocompass or rate of turn indicator. Vessels fitted with AIS transceivers and transponders can be tracked by AIS base stations located along coast lines or, when out of range of terrestrial networks, through a growing number of satellites that are fitted with special AIS receivers.

[1] http://en.wikipedia.org/wiki/Automatic_Identification_System (checked 18 September 2012)

The International Maritime Organization's (IMO) International Convention for the Safety of Life at Sea requires AIS to be fitted aboard international voyaging ships with gross tonnage (GT) of 300 or more tons, and all passenger ships regardless of size. It is estimated that more than 40,000 ships currently carry AIS class A equipment. In 2007, the new Class B AIS standard was introduced which enabled a new generation of low-cost AIS transceivers. This has triggered multiple additional national mandates from Singapore, China, Turkey, and North America affecting hundreds of thousands of vessels. In 2010, the most commercial vessels operating on the EU inland waterways were mandated to fit an inland-waterway-modified and approved AIS Class A device. The entire EU fishing fleet over 15 meters was given until 2014 to do the same. Additionally, a number of other countries, including China, India, the United States, and Singapore, have started AIS mandate programs which require large numbers of vessels to fit an approved AIS device for safety and national security purposes.

In the Baltic Sea the terrestrial network is well established and the AIS messages can be utilised as the primary source for building a position information database.

Expert comments regarding utilization of AIS:

- Worldwide there is a risk of congestion of the AIS network in crowded areas. In the Baltic Sea the risk of congestion is, however, only relevant in summertime, when the icebreakers are not operating.
- Use of AIS Application Specific Messages for sending Ice Waypoints to the ships could be utilised. At the moment the waypoints are sent over AIS, but as AIS text messages, which is not a structured way of presenting the points.
- The local AIS transponder on board the icebreaker may sometimes have difficulties in receiving the AIS signal from a ship being towed or being very close behind the icebreaker. This has to be taken into account in the design of the system (i.e. you cannot rely 100% on the AIS signal).

4.2 e-Navigation[2]

e-Navigation is a concept developed under the auspices of the UN's International Maritime Organization (IMO) to bring about increased safety and security in commercial shipping through better organization of data on ships and on shore, and better data exchange and communication between the two. The concept was launched when maritime authorities from seven nations requested it be added to work undertaken in IMO's NAV and COMSAR sub-committees. Working groups in three sub-committees (NAV, COMSAR and STW), and a correspondence group, as well as the International Hydrographic Organization (IHO) and the International Association of Lighthouse Authorities (IALA), are working on an e-Navigation strategy implementation plan that was supposed to be adopted in 2012.

Along with work taking place under the aegis of the IMO, a number of public and private groups are working to advance e-Navigation and topics related to e-Navigation. Foremost among these are the e-Maritime project within the EU and

[2] http://en.wikipedia.org/wiki/E-Navigation (18 September 2012)

the EfficienSea project coordinated by the Swedish Maritime Administration and the Danish Maritime Safety Administration. Another project in this area is ALIS, which built an e-Navigation framework and prototype aimed at the sub-SOLAS sector.

The work on an e-Navigation strategy implementation plan has been broken down into three phases:

1. Assessing user needs
2. Constructing an open, modular and scalable architecture
3. A series of studies: a gap analysis, cost-benefit analysis and a risk analysis

Consequences for IBNext are that the work on architecture issues could benefit IBNext, and the idea behind e-Navigation to create a new standard for organising the information, could be utilised when designing tools for presentation of map based information to the mariner on board the icebreaker. Another viewpoint is how to deliver and present information originating from the icebreaker to the ship, the most evident being the waypoints through ice.

4.3 MonaLisa/Leonardo

In the MonaLisa 2.0 project (to be implemented in 2012-2014) there is an activity that will study the development of the SEASAR concept for the maritime sector (LEONARDO). The idea is to introduce "Voyage based information" instead of "Surface based operations". This would benefit IBNet regarding handling of information of where the ships are bound for. However, the results will probably not emerge until 2014. Still, when looking for services that could be utilised in IBNext, this is very important.

5 Technical aspects of the system

5.1 Architecture requirements

The big benefits come from a seamless operational system used in the countries around the Baltic Sea. Still there is a need to maintain autonomous operations in the separate countries.

A well-designed architecture, i.e. organisation of how the system is subdivided into modules, their functionality and interfaces both between the internal modules and external systems, makes the system understandable and thus easier to maintain and develop. Additionally, when properly executed, service oriented design paradigm can offer increased flexibility, offering different views of the information geared towards the needs of different user groups.

The architecture requirements are mandated by external interfaces, existing components and wanted functionalities, but otherwise it is a design issue with the goal of satisfying the existing and foreseen requirements as far as possible within the limits of allocated resources.

5.2 Data communication

As it is unreasonable to set up a communications network of its own just for the icebreakers, the communication has to be based on existing networks and technologies. The main alternatives are communication solutions based on terrestrial networks or satellites.

5.2.1 Communication requirements

In short, communication requirements for most information systems can be summed up as requirements for high reliability, high bandwidth and low latency (time between each communication request and the service response).

In an icebreaking information system, reliability is essential but in open sea environment not trivial to maintain. Communication should be arranged so that in addition to the primary communication provider, one or several secondary communication methods are also maintained functional as a backup solution.

For an icebreaking information system, bandwidth is not a primary concern, as in normal operation, the amount of data to be transferred is relatively low. Moderately high bandwidth is required only periodically for the transfer of satellite images.

Low communication latency is an important requirement for the usability of such applications that require an online connection to continuously exchange information with an external party. High latency times make such applications cumbersome to use and therefore impractical. There are solutions based on proxy servers on board that compress the contents of the web page before transmission to and from the ship. They also maintain a local cache that enables reuse of material locally without retransmission. This kind of systems can speed up use of ordinary web pages, and especially if there are several users on board accessing the same pages. However, for applications needing real-time new information from a server frequently, the speed up factor is probably not that high.

Additionally, requirements can be defined for information security in the communication, including confidentiality, integrity (protection from modification) and authenticity of information. Also, non-repudiation of transferred information may be of significance, for example in determining liabilities.

5.2.2 Terrestrial communication networks

When the icebreakers are near the coastline, 3G communications is an alternative, but the limitations regarding proximity to the nearest base station makes use of this communications method to be a backup alternative for special occasions.

Looking forward how the situation is likely to evolve, the most promising alternative is likely to be LTE, an acronym of Long-Term Evolution. Marketed as 4G LTE, it is a standard for wireless communication of high-speed data for mobile phones and data terminals. It is based on the GSM/EDGE and UMTS/HSPA network technologies, increasing the capacity and speed using a different radio interface together with core network improvements.

The world's first publicly available LTE service was launched by TeliaSonera in Oslo and Stockholm on December 14 2009. LTE is the natural upgrade path for both carriers with GSM/UMTS networks and for CDMA holdouts, such as Verizon Wireless, who launched the first large-scale LTE network in North America in 2010, and KDDI in Japan who have announced they will migrate to LTE. LTE is, therefore, anticipated to become the first truly global mobile phone standard, although the use of different frequency bands in different countries will mean that only multi-band phones will be able to use LTE in all countries where it is supported.

Much of the LTE standard addresses the upgrading of 3G UMTS to what will eventually be 4G mobile communications technology. A large amount of the work is aimed at simplifying the architecture of the system, as it transits from the existing UMTS circuit + packet switching combined network, to an all-IP flat architecture system.

Regarding users at sea, LTE is interesting because it can utilise different cell sizes, from tens of meters up to 100 km radius macrocells. Also, data transfer latencies are low (even less than 5 ms for small IP packets), enabling interactive “chatty” applications with frequent request–response packet communication. [Wikipedia http://en.wikipedia.org/wiki/LTE_(telecommunication]

In Finland there was a network called @450 (**Virhe. Viitteen lähdettä ei löytynyt.**) that used the 450 MHz frequency band previously used by the NMT network. The network operator is now a company called Datame. This company has announced that the technology will be changed to CDMA by the end of 2012.

In Sweden the operator “Net 1” offers mobile data communications over the same frequency. The network uses a technology called EVDO (Evolution Data Optimised) which is based on CDMA. The coverage area (Figure 4) is up to 120 km off the coastline. [http://www.net1.se/privat/tackning.aspx]

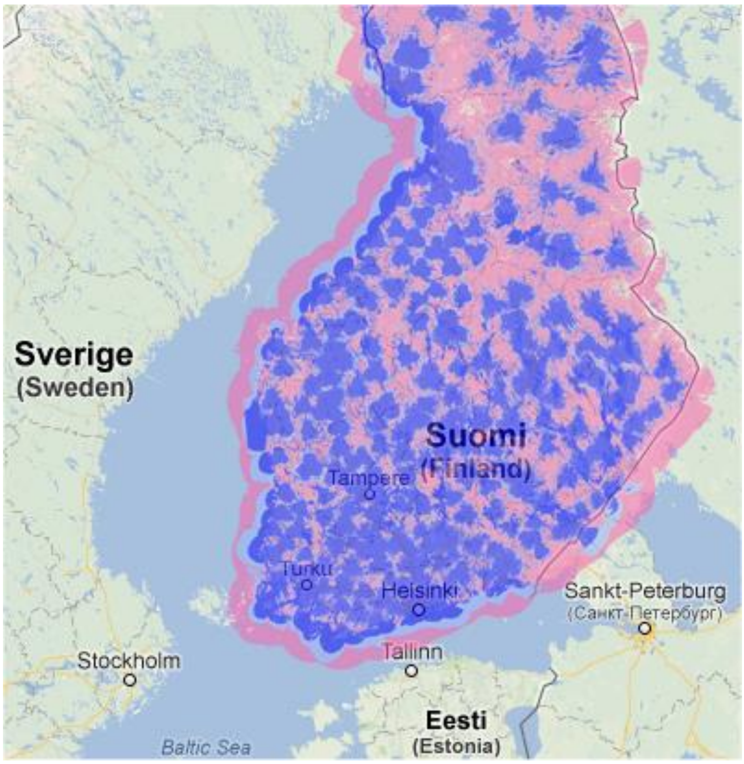

Figure 3. Coverage of the @450 data service offered in Finland by the company Datame Oy.

Figure 4. Coverage area using 450 MHz network offered by the Swedish operator Net 1. Yellow area is the coverage using external antenna.

5.2.3 Satellite communications

The icebreakers are using VSAT technology (Very Small Aperture Terminal) for data and voice communications. This technology is well suited for the relatively limited area where the icebreakers operate and where the latitude does not form an obstacle. The location of the antenna on the ship is a practical problem – if placed up on the highest point, it is vulnerable to vibrations, but a lower placement causes blind sectors in communications. This has been overcome on some Swedish icebreakers by using dual antennas with non-overlapping blind sectors.

Technically the problem with satellite communications is the relatively long latency time caused by the long distance to the communication satellite on geosynchronous orbit above the equator.

5.3 External interfaces

The identified requirements for external interfaces to and from the icebreaker information system can be summarised as:

- Interface to AIS system, both server and on board (see section 5.2)
- Interface to SafeSeaNet or similar to access ship timetable information
- Interface to ship register(s) for static information about ships
- Interface to iceclass information of ships

Table 1 lists the interfaces for those information items that are stored in the IBNet database(s). Information items delivered as separate files, such as satellite images, are not included. The interfaces are at the moment one-way, i.e. very little information is exported from IBNet to other external systems. One consequence of this is that no changes made in the Swedish Ship register are propagated to the Finnish system and vice versa.

Table 1. The most important interfaces of the existing IBNet system towards other operational services (direction of dataflow: IBNet point-of-view).

Country	System	Data contents	Format	Direction of dataflow
Finland	PortNet	Ship register	Database procedure call	Import
Finland	PortNet	Timetable information	Database procedure call	Import
Sweden	Fartygstjänsten	Ship register	Files, XML	Import
Sweden	FRS (fartygs-rapporterings-systemet)	Ship timetable information	Files, XML	Import
Estonia	SafeSeaNet	Ship timetable	Files, XML	Import

		information		
Finland	ENSI	Ice waypoints	Web Service, XML	Export
Finland	baltice.org	Ice restrictions	Files, XML	Export
Finland	baltice.org	assistance plans and situation	XML, javascript	Export
Finland	FMI	Ice restrictions	Files, XML	Export
Finland	FMI	Ice observations	Files, XML/JSON	Export

Deficiencies identified in the present interfaces:

- The ATA information of ships is not necessarily recorded for ships in domestic traffic (Swedish FRS).
- ATA and ATD are recorded with a latency time that is too long for real-time use. Sweden is developing a system (SMMS) which will generate ATD and ATA information based on AIS data and predefined areas around ports.
- Cancellations of port visits are not handled in a consistent way.
- Harmonisation of ship register information in different countries is not fully in place.
- In Finland the interface to the iceclass register is not operational.
- Timetable information that the IBNet users feed into the system, is not exported to any other system.

5.4 Data contents

The database schema of IBNext would largely be based on the same structures and relationships as IBNet, with some small improvements. The most relevant entities are described in the following subsections.

5.4.1 Main entities related to icebreakers and ships

RegisteredShip

- A *RegisteredShip* contains three kinds of attributes: attributes that describes the properties of the ship (for example GRT, NRT, DWT and MachinePower), contact attributes for the ship (phone and fax numbers, owner, captains) and the attributes needed to identify the ship (Name, CallSign, IMO number, MMSI).
- ISNO is the ship key used in the old IRIS system. It is used as a short name, not a unique key in IBNet.
- A RegisteredShip can have 0-n OldShipNames.
- The RegisteredShip can be activated in order to make an ActiveShip.

ActiveShip

- An *ActiveShip* is a RegisteredShip that is currently interesting from the Icebreaker point of view. Thus an ActiveShip exists, when the ship is on a voyage.

- The *ActiveShip* can take the states FreelyMoving, WaitingforIBService, Stopped, Lead, Towed, Supervised and InPort. (Note that a ship can have the state Supervised in parallel with some of the other states).

> Comment: It should be considered whether this entity (ActiveShip) is needed at all. It was introduced to reduce the amount of data to be transferred between the nodes. It may be possible for the system to deduce if a ship is of interest to an icebreaker or not without explicit activation.

Icebreaker

- An *Icebreaker* is a special kind of a RegisteredShip.
- An icebreaker can be in one of the following states: NotActive, Stopped, Assisting, Moving or LocalIcebreaking. Every time the state is changed, an *IBPassage* (ATP) should be generated.
- When an icebreaker is in state Assisting it is associated with at least one current ship Activity in the state Leading or Towing.

Activity

- An Icebreaker gives 0-n current Services that are defined as *Activities* of the ship. An ActiveShip normally has only one current *Activity* in the real world, but in IBNet design model a ship can have 0-n current *Activities*. That enables an Icebreaker to begin serving a ship before the previous Icebreaker releases the ship in IBNET. Also the state of the icebreaker is defined through an *Activity.*
- The state of a ship *Activity* can be FreelyMoving, WaitingIBService, Stopped, Lead, Towed, Supervised and InPort.
- When the Activity starts, a BeginTime and IBPassage (ATP) are saved.
- If the ongoing Activity is Lead, it has an OrderNumInConvoy that shows the order number in a ship convoy led by the Icebreaker.

ShipPassage

- The position recordings of ships and icebreakers are implemented as *ShipPassages.* The activities always begin and end with a *ShipPassage*.
- A ShipPassage has Time and Position of passage.
- An ActiveShip a can have 0-1 current ShipPassages (ATPs) and 0-n estimated ShipPassages (ETPs). An *icebreaker* can have 0-n current shipPassages.

> Comment: It should be considered whether the relation to a ShipPassage should be reversed, i.e. the ShipPassage should refer to an Activity and not vice versa. This would simplify updates and handling of multiple passage entries from separate sources. The connection between the ShipPassage and activity could also be handled as a derived relation that is based on the time information in the Activity.

ActivityPlan

- An icebreaker has an *ActivityPlan* that contains 0-n ships. The same ship can be in many Plans of different icebreakers. The ship can be marked as being FirstInRow in the plan to indicate that this ship will be served next.

ShipDeficiency

- An icebreaker may report 0-n ShipDeficiencies if a ship seems not to comply with the requirements regarding icegoing capabilities. The Operator may verify the report(s) and the information is retained from season to season. All IBnet users can read this information.

5.4.2 Directings and Ice waypoints (DirWays)

IceWayPointList (DirWay)

- An Icebreaker is responsible for keeping 0-n *IceWayPointLists*.
- An *IceWayPointList* has a Name and a Time when the list was last changed last time.
- An IceWayPointList knows its ordered *IceWayPoints*.
- An *IceWayPoint* has a Name, Number, Time of last change and Position.

Directing

- An Icebreaker is responsible for giving *Directings* to ActiveShips. An Icebreaker (or an ETC-user) can give Directings, i.e. directing instructions, to 0-n ships. A ship has 0-1 current Directings.
- The ShipDirectings can have a *InstructionText* describing what the ship must do and the time it was given the instructions.
- A *Directing* can have 0-n ordered *Directingpoints* giving the route that a ship is recommended to use.
- A *Directingpoint* has a copy of Name, Position and Time from an IceWayPoint. The IceWayPoint can change, but the system still knows which waypoints a ship has got and can (in principle) compare the *Directingpoint* with the valid IceWayPoint.
- A *Directingpoint* also has a comment field.

5.4.3 Port Visits

PortVisit

- An *ActiveShip* knows its 0-n PortVisits. The PortVisit describes either arrival at or departure from a Port. The ArrivalTime and DepartureTime are attributes of the PortVisit. If these times are estimates, ArrivalIsEstimate (ETA is given) or/and DepartureIsEstimate (ETD is given) is true. Otherwise the times are actual (ATA, ATD).
- The State of a PortVisit can be Expected, Actual, Passed or OutDated. Only one PortVisit of the ActiveShip can be in state Actual. The Ports and ActiveShips know their own PortVisits.

PortRestriction

- There are 0-4 *PortRestrictions* given to a Port by an Ibnet operator. A *PortRestriction* describes the minimum requirements of ships to get icebreaker assistance when going to or leaving a Port during the time when the restriction applies.
- A *PortRestriction* has ValidBeginTime, ValidEndTime, DWT of the ship, IceClass of the ship and MinLoadPlusDischarge that is the sum of load and discharge in the port. There can also be a minimum MachinePower in the restriction.

- The PortRestriction also knows its ExcludedShipTypes that tells, in addition to other restrictions, the ship types (IBNETShipType) that cannot visit the Port.
- It is the Port that knows its PortRestrictions.

Exempt

- A PortVisit of an ActiveShip can have *Exempt* to arrive at and depart from the Port, even when the ship does not fulfill the PortRestrictions. The Exempt can have an Explanation text.
- An Exempt is valid only for one single PortVisit. The Exempt can only be given by an IBNet Operator.

5.4.4 Voyage

To keep track of the order in which the ship will visit ports, an entity called Voyage exists in the IBnet system. This entity is created locally based on the states and time order of the port visits of the active ships.

Comment: The entity Voyage has created a lot of feedback from the users. The issue is the problem how to handle the information about in which order ships visit ports and how to maintain that information. Port timetable information is imported from external systems both in Finland and Sweden (and Estonia). The information of actual events often arrives with a delay (from a few minutes to several hours). Also there is no global unique identifier for expected visits that could be used between the systems to match an expected visit to possible previous information about the ship visits. To make things more complicated, a time *interval* can be given in IBNet using notation conventions for the minute part of the expected time value. ETA 5.1.2013 1218 would thus mean, according to IBNet conventions, that the ship is expected to arrive between 12 and 18 on January 5th 2013.

IBnet tries to deduce the voyage of the ship based on the time information using an algorithm that first tries to identify which entries concern the same port visit and when it is a new visit. A real-time *voyage service* , not part of IBNet, that would keep track of ship voyages outside of IBnet, could simplify the Voyage handling in IBNet. This Voyage service could be based on the information now delivered to or got from SafeSeaNet combined with AIS triggered ATA and ATD events. It would have to be *real-time* and reliable and cover all ships in the Baltic Sea that are relevant in winter time.

5.4.5 IBNet source and Local IBNet users

Each source of information within IBNet has a unique identifier. The source may be related to an icebreaker, an Operator or to other users like a VTS user (called ETC users in IBNet jargon). Also converters that import information from external systems are given an identifier (like P@N for PortNet).

Comment: The number of sources in IBNet has increased all the time. It might be necessary to introduce some kind of grouping of the sources or to use longer identifiers in the user interface for these to make the list of sources understandable to the IBNet users.

Within a node it is possible to define Local IBNet users that share the same IBNet source ID but have separate recordings concerning what messages they have read.

5.4.6 Messages and Day report

An IBNet source can write 0-n messages. The message is distributed to all other IBNet users. A message has a header, time and position. It contains text where the user should write about the intentions and other information that is relevant for the icebreaking service. A message can contain a weather observation and an ice report.

An Icebreaker can write a DayReport describing a summary of the assistance activities (in hours and miles) for the past 24 hours. The default for this report can be generated automatically from the activities stored in the IBnet database The day report also contains information about next bunkering and crew change. Also fuel consumption is entered here.

5.5 Database replication

To guarantee autonomous operations even when the telecommunications are temporarily broken, a local database is needed to make access possible for the local users. A mechanism is then necessary to synchronise the contents of the databases in the different nodes.

In the IBNet system, a proprietary replication mechanism was designed because of the lack of desired features in the existing solutions at that time. Now the situation may have changed, but the challenges concerning asynchronous replication is still there, i.e. how to handle conflicts when there are multiple updaters of the same entity and there is a delay in the propagation of the information. There are commercial systems enabling asynchronous replication, and a technical trials of the most promising ones is recommended.

The proprietary replication system in IBnet could also be used as basis for the next generation system if some of the present imperfections would be amended. The most important issues are listed in **Virhe. Viitteen lähdettä ei löytynyt.**.

The recommendation for IBNext is to avoid database updates when there are many updaters of the same entity. If the owner of the table/record can be clearly defined so that there is only one source that is allowed to update that record, there is no risk of conflicts. However, when there are multiple updaters, like ship timetable information, the strategy would be to transfer events only as inserts in the database. The end result is then synthesised based on the simple events that have arrived and can be attributed to the same larger event. An example is information about estimated arrival of ship to port: all pieces of information are gathered but the result is locally deduced at the node without updating the individual event records.

Another way would be to establish a ship voyage service on shore that would provide unambiguous, real time information about the voyage plans of all ships in the area of interest.

Table 3 lists the most important entities of IBNet and whether they are updated by a single source or if multiple sources are allowed to update the records, potentially causing conflicts that need conflict resolution algorithms. The design effort should be concentrated on the elements that have multiple updaters.

Table 2. List of issues related to the replication system.

Issue	Problem	Correction	Advantage	Risk
Format of update/diff messages between the nodes	Now the format is a proprietary binary format which requires all nodes to have exactly the same schema	Use XML or JSON	Extensibility better. Upgrades of the system more robust	Increased data volume. Rather large work to implement in present IBNet.
Topology of IBNet nodes must be a tree	No loops are allowed; redundant replication paths are therefore not possible	Higher level message interchange	More robust overall system	Quite large change in architecture.

Table 3. List of IBNet entities and their property regarding updaters. Single updater entities are preferred because then no conflicts can occur in case of asynchronous replication. In the Multiple updater case there is always a possibility for conflicts and a conflict resolution algorithm must be applied.

Entity	Updaters (Multiple/ Single)	Comment	Replication complexity (0 - 3). 3 highest
PortVisit	M	To aggregate the port visits that belong to the same visit and implement an intuitive User Interface is not a trivial task.	3
RegisteredShip	M	Conflicts can occur if the information from different ship registers differ. These conflicts have to be flagged and resolved manually.	3. A tool /user interface for manual conflict resolution must exist. Problems restricted to the centers only.
ActiveShip	M	Latest information applies.	2
Activity	M (icebreaker activity is S)	Ending of an activity must be synchronised with the beginning of next activity, which can be initiated by a different entity than the one that created the Activity	2
Icebreaker	S		1
ShipPassage	S	A ship passage records the time and position of ships (and icebreakers)	1

Entity	**Updaters (Multiple/ Single)**	**Comment**	**Replication complexity (0 - 3). 3 highest**
AssistancePlan	S	The icebreaker maintains its own assistance plan	1
IceWayPointList	S	Also known as DirWay	1
IceWayPoint	S		1
Directing	S		1
Directingpoint	S		1
PortRestriction	S	Only operators can give restrictions	1
Exempt	S	Only operators can give exempts	1
IBNetsource	S		1
Messages	S		1
DayReport	S	previously WeekReport	1
RefCodes (global parameters)	m	Only Operators are able to generate/update. Low risk of conflicts.	1
ShipDeficiency	m	Icebreakers generate, operators update	1
Voyage	generated locally	The Voyage issue is complicated as such.	0, The complexity is in the PortVisit
localIbnetuser	used locally		0
LocalParameters	used locally		0

5.6 User interface and map technologies

The IBNet user interfaces have been implemented using two different environments/languages: Visual Basic version 6 and Java. The map based user interface is implemented in Java and the other elements in Visual Basic.

The existing IBPlott user interface has been developed and incrementally enhanced over the years in close communication and interaction with the users and is therefore a good candidate also for the next generation system. However, IBPlott can be seen to need a refurbishment effort to modernize the look-and-feel and usage of the user interface, and making it more consistent with other similar applications.

Appendix 1 presents an analysis of the IBPlott user interface and suggestions for improvement.

As an alternative there is the question whether there are new (generic) technologies that could be utilised for an efficient implementation of the map based user interface of the system. There exist Situation awareness systems for rescue and other operations and the question is what the needed effort is to adopt such a system to the needs of the icebreakers. The answer depends on what platform to start from: different manufacturers have different starting points and taking a generic platform as the basis brings a lot of generic elements not necessarily needed for the application at hand.

The current implementation technology of the IBNet components IBBridge, IBOperator and IBparameter – Visual Basic 6 – is now rather old. Regarding these components, an analysis similar to the one done for IBPlott would be required.. Although the majority of the users seem to prefer two distinct and separate IBNet user interface applications, user training, maintenance and further development would be easier and less costly if the current IBBridge functionality was transferred to the same platform as IBPlott. The implementation could still support having the form based functions on one screen and map based view on another screen, while also enabling integrated use on just one screen if preferred.

5.7 Multiple domains of control

Recommendations issued by the IT departments in the Administrations in Finland and Sweden are helping the IT operators to maintain and monitor the different applications in a consistent way. The recommendations also help the application developers to take advantage of already existing services, if possible.

In general, service oriented design approach is recommended both in Sweden and Finland. The applications are built on existing service elements with defined interfaces. Such service elements are ship registers and voyage monitoring services.

A specific issue to address is that the icebreaker information system needs to interface with service elements in several countries, which may cause problems if the information is not consistent. On the other hand, this enables flagging of suspicious information raising the overall quality of the data in IBNet.

On the Finnish side a guiding document called “Liikennevirasto – Verkkopalveluiden viitearkkitehtuuri” defines the recommendations from the IT department of the Finnish Traffic Administration.

6 Organisational aspects

Development and maintenance of IBNet is currently administered via development projects. When going into an operational phase, the development process is still valid for introducing new features, but it is equally important to organise maintenance of the system in an efficient and satisfactory way.

Distinctive to IBNet is its distributed operation over several countries. The ownership of the present system is shared, which is a working model as long as the owners agree on development guidelines and organisation of maintenance etc. If the user base is enlarged, the ownership issue has to be considered carefully, especially when developing a new system or distinct parts thereof. The management of the operations and development should be formalised to guarantee a smooth operation and development of the system as the needs and the operating environment change.

The administration should not be over-organised in a bureaucratic way, but documented rules and guidelines are necessary to guarantee continuity in the long run, when people may change and partners are reorganised. It is also good to remember that any IT system is merely a tool for supporting the operational cooperation. The rules and processes have to be decided between the organisations involved in the participating countries.

The organisation could consist of a Steering Committee having authority to make financial decisions within budgets decided in each participating country. This Committee would gather minimum once per year. A Technical Committee could consist of persons knowing the technical issues and these persons could then prepare decisions to the Steering Committee. A User forum could be established. This could be done using some social networking tool + regular user meetings (once per year minimum). An issue tracking/reporting system could facilitate organization and follow-up of discovered errors that require correction, as well as identified development needs.

Regarding maintenance a large issue is to what extent the work can/should be outsourced. Some in-house competence is important to maintain as a risk mitigation method, but the in-house organisation might not be as well suited to IT maintenance as an external IT service provider.

7 Gap analysis and roadmap

The conclusions of the study are that the present system satisfies most of the currently identified requirements. However, there are deficiencies that should be addressed.

- Robustness. The availability of the system should be high enough, so that the users can rely on the system even if the data-communications link is temporarily out of order. The users should also be able to have trust in the information content and knowledge of how to correct erroneous information.
- Improved handling of ship voyage information. This information is now considered difficult to correct and manage. Ship voyage information could possibly be handled by a separate land based service, to which IBNet would interface.
- Improved ways of handling installation and upgrades of the IBNet applications.
- Facelift and reorganisation of the user interfaces.
- Modifications to the underlying data model. Redesigning some relations between passages, port visits and activities would simplify much of the logic, especially in cases when erroneous input has to be corrected.
- Organisational issues. Organising the IBNext development and maintenance, and determining the vision for the ownership of the system.

The priority of next steps depend on whether there is an interest to enlarge the user base also to other countries around the Baltic Sea, especially Russia. Funding opportunities may exist for such a development work. In this case the first step would be to investigate in what way the system could be enlarged to encompass such a large player with dense ship traffic. A separate focused prestudy is recommended to investigate the possibilities for extending the cooperation network to Russia, either by interfacing to a Russian traffic information system or by developing a joint information system.

If the user base is kept as it is (Finland, Sweden and Estonia), cost estimates for different development alternatives should be made as part of the cost/benefit analysis.

A possible roadmap for the development is presented in Figure 5.

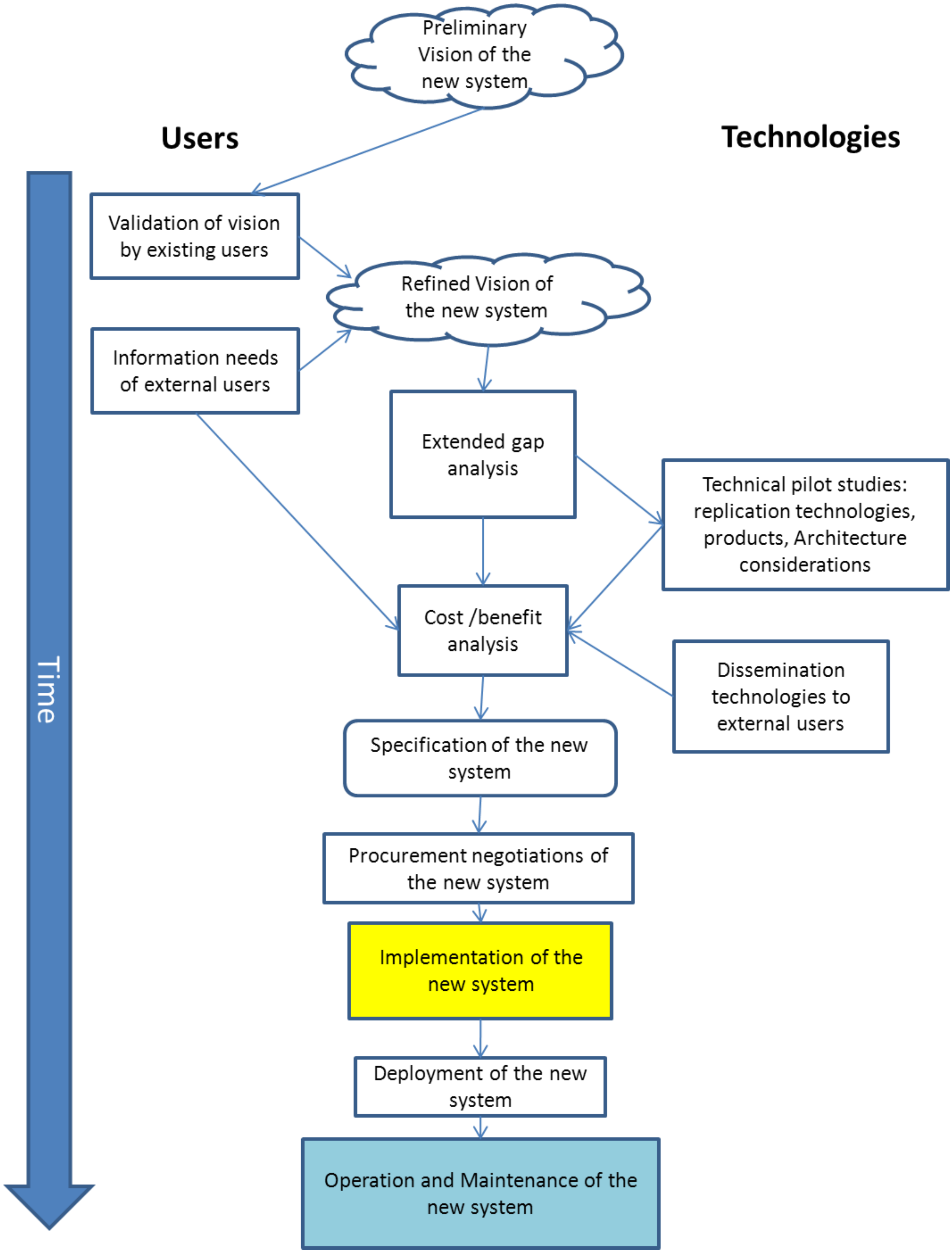

Figure 5. Suggested roadmap for development towards IBNext.

Appendices

1) IBPlott user interface study

References

[R1] Description of IBNet
[R2] IBNet architecture review – development possibilities, requirements and scenarios, 2005
[R3] Prestudy concerning extension of IBNet to Estonia, 2008