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Study on Small Vessel's Pseudo-AIS Interoperable with Universal AIS

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Abstract : *Universal AIS, which has been adopted officially for automatic identification systems among regulated ships by SOLAS, should be installed, for example, on all passenger ships over 300 tons engaged in international voyage and over 500 tons in domestic voyage, sequentially from 2002 to 2004. We must not overlook the fact that many marine casualties happen in small vessels not regulated by SOLAS, as well as un-ruled regions by regional authorities in the case of VTS. Actually a major portion of accidents have happened in small vessels like fishing vessels. However, they are not equipped with automatic identification tools, due to the high costs of the equipment for identifying purposes, as well as the absence of regulation. In this paper, we researched the alternative of automatic identification for small vessel instead of universal AIS. We analyzed the requirement of automatic identification for small vessel about wireless communication method, traffic volume, etc. We proposed the identification system for small vessels in local areas and developed the Local Vessel Identification System (LVIS) interoperable with universal AIS using a PDA platform and wireless network.*

Key words : *AIS(Automatic Identification System), mobile platform, satellite navigation system (GPS), mobile communication*

1. Introduction

Most accidents of ships are huge as can be seen in the cases of the sunken ferry in the Yellow Sea of Korea at Oct. 1993 and the tanker "Sea Prince" at July 1995. We have experienced the physical and economical damage even by one accident that is followed by an environmental disaster.

In these days, the ocean becomes a valuable and last source for human, which could be a key point for the wealth of Nation. We need to construct the system of monitoring and managing the ship's traffic in order to prevent the accident of ship, which leads to minimize the damage of human, economy and environment. The most important thing of these is to identify the moving target position of the object in real time that is commonly observed in the ocean such as ships, buoys, etc. It is described in Table 1 - the statistics of marine accidents in the annual MOMAF marine statistics in 2002.

From Table 1, the accidents of over 500 tonnages are graphed relative to that of less than 500 tonnage ships in Fig. 1 in which we can understand most accidents happen in less than 500 tonnages.

There may be many reasons that many accidents happen in small and middle ships. Most of all, it is the main reason for the lack of safe navigation systems for small and middle-sized ships. In view of ship's equipment, their owner tends to equip only mandatory system for their own ship, so its safety can't be acquired to a sufficient level to identify the position of surrounding ships and dangerous things to navigate. The equipment for advanced technology like AIS is too expensive to install at small size ships. Moreover, the AIS is not a mandatory equipment of small ships which are not regulated by SOLAS. When the traffic management system is operated to monitor and manage various sizes of ships in a region, a way of identifying small ships should be developed like the AIS in a case of large vessels.

Table 1 Number of Marine Accidents

	1998	1999	2000	2001
Below 5 tons	182	182	120	143
6-20 tons	136	196	134	133
21-50 tons	142	178	149	145
51-100 tons	215	216	169	144
101-200 tons	63	66	48	41
201-500 tons	29	36	24	23
501-1000 tons	29	24	31	43
1001-2000 tons	31	32	30	27
2001-5000 tons	31	27	32	34
Over 5000 tons	31	37	22	37

(Source : MOMAF Statistics 2002)

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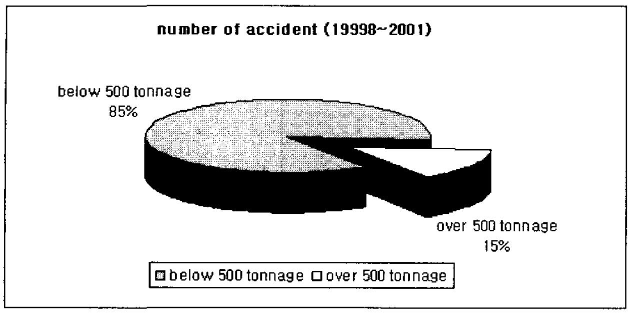

Fig. 1 Accident by tonnage group

2. Marine Traffic Management System

2.1 Existing systems

To prevent the accident in heavy traffic regions like harbors, canals or coastal areas, there are traditional ways of VHF communication or RADAR that are used widely. However, they have limited capacity of non-active systems not to identify object's information. Currently, there are 12 sites of VTS (Vessel Traffic System) named as PTMS(Port Traffic Management System) consisting of VHF, RADAR, CCTV, etc. in Korea.

The Radar is still an important tool to calculate a relative distance but also has a disadvantage. If there is an obstruction between own ship and another to detect, radar can not detect any echo from the target. We called it shadow zone of radar caused by non-line of sight. In addition, radar signal can be degraded by weather condition or the status of ocean waves. Especially, target swapping can happen when two targets are navigating too closely. The ARPA is to identify the movement of target, so it can not get any information of the other ship automatically.

In the case of VHF communication, there may be a critical situation that the designated channel of VHF communication of all ships is wholly seized by a corrupted VHF receiver or human error, known as KEYING, which makes the other mariner not being able to communicate by the seized channel. It will make a dangerous situation of not being able to communicate between the monitoring operator in the center station and mariner onboard.

The AIS is developed and adopted by IMO (International Maritime Organization) as an alternative for identifying ship's position automatically and interrogating the specific ship's information. It could be used by ship mariners who want to monitor traffic environment around own ship and by VTS operators to check the ship's call sign, purpose, destination and current speed, etc. The AIS is expected as the key equipment to improve ship's safety of navigation.

2.2 Automatic Identification System

AIS is an autonomous and continuous broadcast system, operating in the VHF maritime mobile band. It is capable of exchanging information such as identification, position, course, speed and more, with ships and shore. Initially called the "Ship-Ship, Ship-Shore (4S)" broadcast transponder, this technology formed the basis of what eventually became known as the "Universal Ship-borne AIS".(Ministry, 2002)

The AIS can be used as an identifying tool of ship-to-ship and between ship-to-shore station by communicating the information through designated VHF channel including ship's position, course, speed and others. It is operated automatically to send its own information and receive other ship's information, even to relay information. The ship can avoid the collision easily and acquire target's information automatically by AIS. The AIS mainly consists of three modules such as a sensor, main processor and VHF transceiver. The sensor part includes an internal GPS that provides timing information and a function of backup in case of failure of external GPS sensor. There are two VHF transceivers in AIS that operate the function on two channels, AIS A and B simultaneously. Finally, main processor manages information process, display of received information and controlling other modules. This system is an evolutionary technology to replace current identifying system, which is adopted by IMO as a mandatory equipment of SOLAS. The IMO has amended the SOLAS Convention that all vessels more than 300 tonnages on international voyage and over 500 tonnages on non-international voyage have to install the AIS by a specified schedule, which is mandated from July 2002. It will be very useful to know not only ship's position and information related navigation but also cargo information. As far as a statistics, many countries are building the AIS reference stations on coastal areas of their own and ship stations of AIS is being installed onboard.

As described before, AIS must be a useful and the most effective way to reduce ship's danger situation but is likely to be installed on large vessels regulated by SOLAS. However, we can see that most accidents certainly happen in small and medium size ships as described in Table 1 and Fig. 1. They are not likely to install the AIS because of cost or a reason that may be that the functionality of AIS is not fitted to small vessels. Although there is a Class B transponder specification for the ship not regulated by SOLAS, it is still a draft and its concept is not appropriate for small vessel's requirements. From these reasons, we can understand the need of another way of identifying for small vessel.

3. Pseudo-AIS for Small Vessels

3.1 Consideration of small vessel's pseudo-AIS

When the method of small vessel's identification was developed to install and use in real life, there were many considerations such as wireless networks, cost of equipment and operation, small vessel traffic and interoperability with universal AIS. In this paper, we considered first wireless network.

1) Wireless communication

The AIS adopted the VHF frequency to communicate and need VHF transceiver that is expensive to use in low cost system. So it is necessary that we develop an alternative way to communicate each other in a sense of network which is likely to be operated in the universal AIS. Korea has the technology of CDMA wireless network and other communication infrastructure. Several ways of wireless communication that can be observed in Korea are described in Table 2.

Economic aspects about wireless Internet rate and communication range should be considered preferentially for small vessel's pseudo-AIS. The TRS is the most suitable communication. Although Trunked Radio System (TRS) hasn't perfect network over whole country, users are increasing steadily and continuous station's setup is being propelled. Because it is expected that TRS service area is magnified and quality becomes superior, it is the most suitable communication method for small vessel's identification system.

Table 2 Comparison of communication

	PCS	Cellular	Paging	TRS	Satellite
Provider	KTF(016/018) LG(019)	SK(011/017)	REAL(015) HAPPY(012)	KT(0130)	INMARSAT Iridum, etc.
Signal	Digital CDMA	Analog AMPS /Digital CDMA	Flex FOSAG	TDMA	CMDA. TDMA, etc.
Quality	Very good	Good	Good	Very good	Medium
Security	Good	Good	Good	Medium	Good
Frequency	1.7~1.8 Ghz	800 Mhz	138~174 MHz 322~328 MHz	380MHz 800MHz	1~40Ghz
Range	3~10 km	10 15 km	20~30 Km	20~50km	Whole world
Efficiency	Good	Good	Very good	Very good	Medium
Service	Voice, Data	Voice, Data	Number, Text	Voice, Data	Voice, Data, Facsimile
Cost	Medium	Medium	Low	Medium	High

2) Cost

In reality, AIS is a very expensive equipment that is fairly difficult for small vessels such as fishing boats to equip. Because the purpose of this research is the acquisition of automatic identification way for small vessels, cost must be a very important consideration and must be cheaper than AIS setup expense. Specific items were not confirmed at present, although International Maritime Organization (IMO) is proposing the concept of class-B type AIS transponder that is a lower grade than universal AIS. Lately, receive-only AIS transponder is sold in low price, but it is impossible for multiple communications and insufficient to use for automatic identification for small vessels.

Technologies for the Personal Digital Assistant(PDA) and mobile telecommunications are evolutionary today, due to the growth of wireless Internet. PDA is one of the mobile platforms and is composed of the mobile wireless communication device. Nowadays, technologies related to the Location Based Service (LBS) on mobile platforms are also being developed.

If PDAs and wireless communication are combined for automatic identification, a construction of a system that is inexpensive and highly efficient may be possible. However, "per packet rate" of wireless Internet is an item that should be considered necessarily for the cost of the system. It is an available solution into minimization of packet or using equal rate. Therefore if wireless Internet based pseudo-AIS is developed, it may be used by a reasonable system in communication range.

3) Small vessel's traffic volume

Because Republic of Korea has a long coastline than the country area, and coast waterway that is formed along the coastline is overlong, vessel's traffic volume is very heavy. Therefore traffic volume of small ships which are non-SOLAS convention vessel is heavy as well. There is an example that analyzes about AIS target entry vessel in the future in "Pilot Project Report - Introduction of AIS": Ministry of Maritime affairs and Fisheries(2001).

AIS is expected to be installed on almost every vessel in hereafter. However, the ratio of vessels traffic volume without AIS (small vessel) traffic volume may appear as higher ratios, if the proportion of vessel traffic volume with AIS supposes to appear about 59.5% to 2008.

4) Connection with Universal AIS

Small vessel's pseudo-AIS needs to associate with Universal AIS. In other words, there is difficulty in preventing accidents due to the information interchange with existent AIS ships, not being consistent to only small vessel's pseudo-AIS. Therefore, if information interchange between small vessel and AIS ship is available, system is efficient. Small vessel through this information interchange can know AIS vessel's motion that sail on surrounding, and prevent collision accident between both sides. In addition, AIS vessels need to know small vessel's position. If AIS vessel does not depend on sight viewing or radar observation and can identify non-AIS small vessel automatically in heavy traffic zone, AIS vessel's mariner will become less tense and it may be possible to prevent ship accident. In order to transfer the AIS information to small vessels, it may be necessary to interpret the message from AIS base transponder. International Electrotechnical Commission(IEC) have drafted the sentence for AIS that will be finalized to the end of this year. One of them, VHF Datalink Message(VDM) is a sentence that can output surrounding target information that AIS receives. In this research, we suppose that AIS transponder outputs VDM sentence, and then small vessel's pseudo-AIS server analyzes this sentence, and transmits the message to small vessels.

3.2 Proposal of small vessel's pseudo-AIS

We examined the consideration of pseudo AIS for small vessel in several sides in chapter 3.1. For wireless communication of small vessel's pseudo-AIS, TRS is the best solution. Moreover, mobile platform as PDA and multiple direction wireless Internet based pseudo-AIS is developed, it may be efficient system for small vessel. However, TRS is lacking to use in application system development in present situation, because of communication infra structure and development kit insufficiency. Therefore, we proposed 『Local Vessel Identification System (LVIS)』 that is developed using mobile platform PDA and wireless Internet CDMA KIT using cellular phone for non-AIS small vessels' pseudo-AIS.

Table 3 Estimation of vessel traffic with AIS (2002~2008)

Year	Vessel traffic	AIS vessel traffic	Proportion(%)
2002	145609	-	0
2003	146106	14714	10.0
2004	146605	16879	11.5
2005	147100	31162	21.2
2006	147597	44780	30.3
2007	148095	70084	47.3
2008	148772	88450	59.5

4. LVIS(Local Vessel Identification System)

4.1 Concept of LVIS

It is the main purpose that LVIS permits information interchange with AIS installation ship and automatic identification between small vessels. LVIS Server can pass information that is collected in AIS base station to LVIS clients by radio communication and re-transmit information that is reported in LVIS Client to all clients. If client's information that is collected by LVIS server offer to AIS base station after changing to AIS signal, it may become possible that AIS vessel grasps small vessels' position. Using LVIS, small vessels can grasp AIS installation ship's motion that is around without going through radar or VHF communication. And AIS installation ship can grasp small vessel's motion as well.

In this research, we used the CDMA 1.x kit for wireless communication that is currently widely available in Korea. Because CDMA for radio wireless Internet environment have the restriction of range, we set constraint condition that "LVIS system is used in VTS area or coastland of harbor and bay." Actually, accidents of collision happen much near harbor and bay or coastal zone relatively than far sea. Therefore, above constraint condition is reasonable. In the future, when the restriction of distance relieves and TRS communication is more available, above constraint condition is released.

4.2 Communication between LVIS components

1) Communication between LVIS Server and Client

Communication between LVIS Server and Client is to "1)" in Fig. 2. LVIS server creates LVIS message ($LVSVR) from output message of AIS base station, and then transmits them to LVIS client by wireless Internet communication. Because Wireless Internet is multiple direction communication that is used in LVIS, information interchanging between LVIS Server and Client is available. Giving a particular function to LVIS server, LVIS Server may transfer selective information to client.

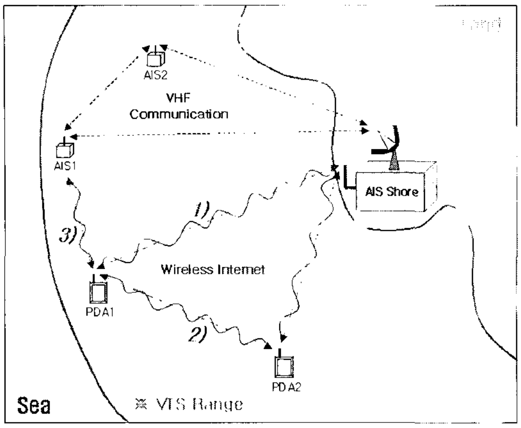

Fig. 2 Concept of LVIS

2) Communication between LVIS Clients

Communication between LVIS Clients is to "2)" in Fig. 2. LVIS server transmits message ($LVCLT) that is received from LVIS clients to other clients with AIS message. Therefore, direct communication does not consist between each clients of LVIS system. LVIS client confirms other clients' information connecting to LVIS server, and exchanges information.

3) Communication between LVIS and AIS

Communication between LVIS and AIS is to "3)" in Fig. 2. Actually, AIS transponder uses VHF and LVIS system appropriates wireless Internet that use CDMA communication. Therefore, direct communications between two systems do not consist. However, if technology for AIS development is secured domestically later, AIS Base transponder's correction may permit direct communication through input messaging from LVIS server to the AIS Base transponder.

4.3 Components of LVIS

LVIS is consisted of "LVIS server" and "LVIS client." Function that "LVIS server" analyzes AIS message that is output from AIS Base station and transmits through wireless Internet, and have function that transmit information that receive from each LVIS client to all clients. Through wireless Internet communication between LVIS server and LVIS clients, each LVIS clients can have the information of LVIS installation ships as well as information of AIS installation ships.

1) LVIS message

Message that exchange between each component of LVIS system is three. First is AIS message (VDM) that is output from AIS transponder, and second is message that is offered by each client in LVIS server, and third is message that reports own information to server in LVIS client. In this research LVIS messages were consisted of test form similarly with NMEA-0183 format.

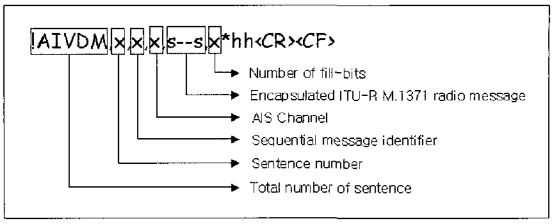

Fig. 3 AIS sentence (VDM sentence)

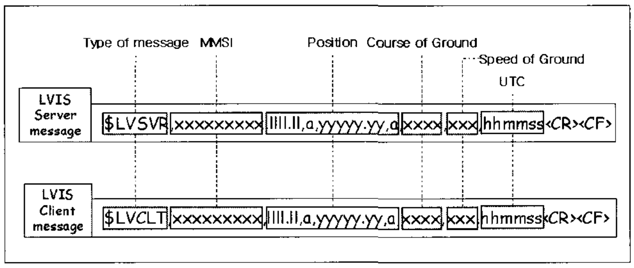

Fig. 4 LVIS message ($LVSVR & $LVCLT)

▣ VDM massage ("!AIVDM")

As one of AIS sentence that is included to revision of IEC 6112-1, VDM is a message that outputs surrounding target information that AIS receives. In this research we used ITU-R M.1371 message 1, 2, 3 and offered User ID(MMSI), longitude and latitude, Course of ground, Speed of Ground, etc.

▣ LVIS Server message ("$LVSVR")

LVIS server message that is transmitted from LVIS server to LVIS clients is consisted of sentence such as Fig. 4 "$LVSVR~" parsing VDM message that is input AIS Base transponder. Contents of message were consisted selectively according to necessary order among VDM message that is input from AIS transponder.

▣ LVIS Client message ("$LVCLT")

LVIS client message is a transmitted message from LVIS client to LVIS server. We changed NMEA-0183 that is input from GPS in sentence of "$LVCLT~" form like Fig. 4 for LVIS client message. Position information, Speed, Course, MMSI, etc. is included in contents of message.

2) LVIS Server

LVIS server program grasps LVIS client's state that is

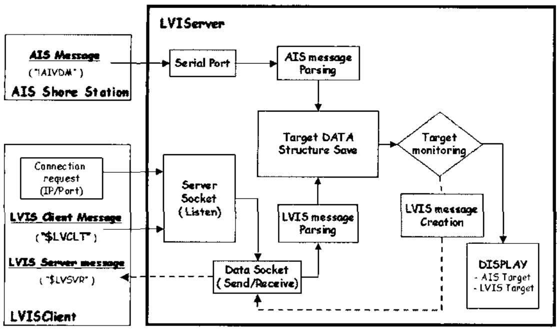

Fig. 5 LVIS server Data flow diagram

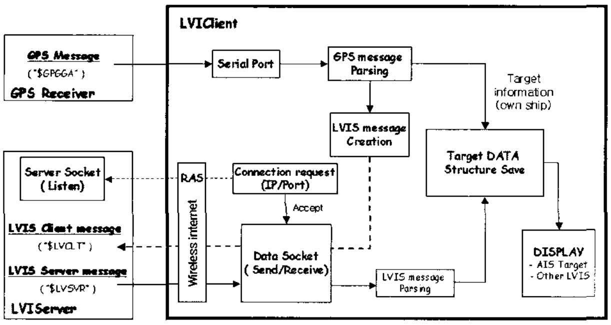

Fig. 6 LVIS client Data flow diagram

connected to wireless Internet, and parsed AIS message and transmit to each clients. LVIS server is consisted of "Serial Communication Part" that process input AIS message and "Socket Communication Part " that process that LVIS client message input from LVIS client and "Display Part" that store message that is input from various input sections to Target structure information and display on screen.

LVIS server's main functions are as following.
- AIS message reception that use serial port control
- AIS message parsing and LVIS server message creation
- AIS ship indication (Display) / AIS ship monitoring
- Socket server role (Listening)
- LVIS message reception and parsing
- LVIS ship indication (Display) / LVIS ship monitoring
- Message transmission to connected LVIS clients

3) LVIS Client

LVIS client is a user side program that connects and registers own ship position to LVIS server, receives AIS or other clients' information. LVIS client is consisted of "Wireless Internet connection Part" that use RAS-API (Remote Access Server Application Programming Interface) and "Socket communication Part" for message send-receive and "GPS positioning" that use RS-232C.

LVIS client's main functions are as following.
- Wireless Internet connection
- GPS single positioning
- LVIS client message creation
- Socket creation and connection to LVIS server(IP, Port)
- Own ship information reporting to server
- Message ($LVSVR) reception and parsing form server
- Display own ship and server message (other ship)

5. Field Test of LVIS

5.1 Implementation of LVIS

LVIS client receive LVIS Server message ("$LVSVR") from LVIS server using wireless Internet connection after the client establish a connection between LVIS server and the client with LVIS client message ("$LVCLT"). LVIS server is developed in the form of the desktop-PC based application program with Visual C++6.0(Microsoft) and LVIS client is the PDA program coded by embedded Visual C++(Microsoft). In this research, we developed "VDM signal simulator" for system realization that acts as an equal role of the AIS base transponder because we couldn't directly receive AIS message from base transponder until now.

5.2 Field Test of LVIS

We developed and implemented an LVIS server and clients described before. We installed LVIS server in laboratory and LVIS client on vehicles for field test with simulated VDM message.. This test was carried out for the verification of the availability of LVIS system in a field.

We can see the Fig. 7, the 32 ton passenger ship used for the experiment. This passenger ship plies between Mipo Wharf in Busan and Oryuk Islets for about one hour.

One server and one client were used for experiment. LVIS client was installed in the vessel and LVIS server was located in Daejeon. Fig. 8 is LVIS server's execution screen, which is a display to present of parsing and displaying received information from connected client. And it also present one AIS vessel near Busan port area, which is simulated in laboratory. We could recognize that black AIS target on the left and red LVIS client on the right side were automatically identified at the same time. In addition, we could see that LVIS message transmission between LVIS server and LVIS client that use wireless Internet is achieved harmoniously as seen in Fig. 8.

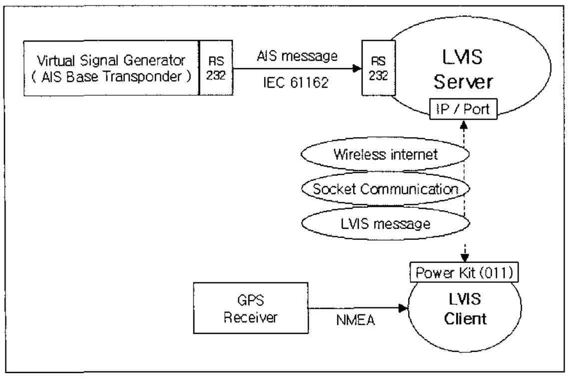

Fig. 7 Vessel for experiment

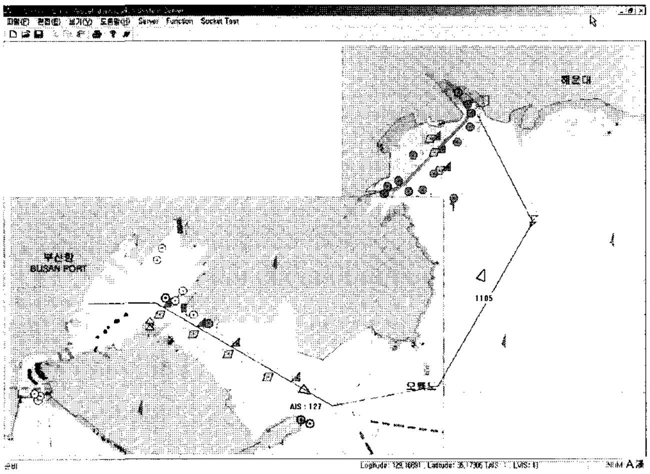

Fig. 8 LVIS server program execution

5.3 Expected maintenance fee derived from field test

Table. 4, Table. 5 and Fig. 9 are statistical data that analyze "wireless Internet rate" that is expected for various kinds sides according to various reporting rates. Reporting rates of target are referred from AIS reporting rates of the target. Recently, wireless Internet assessment has changed

Table 4 Statistical data by message reporting rate

Reporting rate (sec)	5	10	15	30	60	600	1800
Used data per day (KB)	432	216	144	72	36	3.6	1.2
Rate per day (Won)	1296	648	432	216	108	10.8	3.6
10Knot Ship reporting rate (m)	25.4	50.7	76.1	152.1	304.2	3041.7	9125
20Knot Ship reporting rate (m)	50.7	101.4	152.1	304.2	608.3	6083.3	18250

※ **Principles**
Mobile communication available zone
Heavy traffic, low speed zone - Only Reporting
LVIS message : 50 byte / 1 message
Day(12 hour) Wireless communication rate : 1.5 Won / 0.5 KB

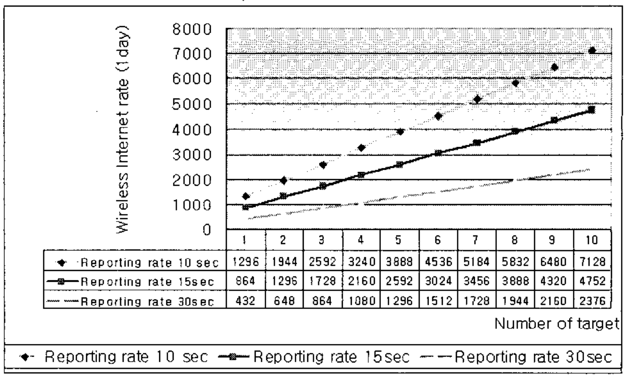

Fig. 9 Internet rate(WON) by no. target & reporting rate

from "per Packet" to "per 0.5 KB" in KOREA, and it is 1.5 won per 0.5 KB. As it can be assumed in Table. 4, "30 second Reporting rate (216 won per day)" is the most economical case. If a 10 knot speed vessel reports every 30 seconds, the vessel reports in 152.1m every time. Therefore, it is a reasonable case in automatic identification for a small vessel. Table. 5 displays rate by transmission amount that happen according to the target number. Although we manufactured LVIS messages in text form, it may reduce data amount very much if correct LVIS messages are in binary form. Because the below result is the calculate rate of information transmission continuously 12 hours per day, Internet-rate is expected to be very cheap in actual situation.

Table 5 Internet rate(WON) by no. target & reporting rate

Reporting(sec) / number of target	5	10	15	30	60	600	1800
1	2592	1296	864	432	216	21.6	7.2
2	3888	1944	1296	348	324	32.4	10.8
3	5148	2592	1728	864	432	43.2	14.4
4	6480	3240	2160	1080	540	54	18
5	7776	3888	2592	1296	648	64.8	21.6
6	9072	4536	3024	1512	756	75.6	25.2
7	10368	5184	3456	1728	864	86.4	28.8
8	11664	5832	3888	1944	972	97.2	32.4
9	12960	6480	4320	2160	1080	108	36
10	14256	7128	4752	2376	1188	118.8	39.6

※ **Principles**
- Mobile communication available zone
- Heavy traffic, low speed zone
- LVIS message : 50 byte / 1 message
- Day(12 hour) Wireless communication rate : 1.5 Won / 0.5 KB
- Only Reporting · Did not divide AIS / LVIS Target

6. Conclusion and Recommendations

We knew that many ship collision accidents happen in small vessel analyzing accidents of "2002 statistical year book maritime affairs and fisheries." Because it is unprepared for maritime traffic management system for small vessels, we studied about the necessity of automatic identification for small vessel and specific alternatives. We analyzed the consideration of small vessel's pseudo-AIS. We also proposed and developed LVIS with these considerations. We developed LVIS system that is consisted of LVIS server and LVIS clients, and confirmed that it is possible for small vessel's identification implementation using wireless Internet. From now on, additional arrangement of stations and extensions of range and quality sophistication of wireless Internet that CDMA is used are expected. Therefore, wireless Internet application extent of systems may be magnified according to wireless communication alteration. In addition, automatic identification technology of LVIS may be used on application systems like aids-to-navigation management systems. In this paper, the presented result was made before the field test; therefore, we will add real considerations of automatic identification with field tests and correct to supplement LVIS. As the development of LVIS, we expect to contribute for the prevention of marine accidents in all classes of vessels.

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References

[1] JK Chae(2003), "Prospect of Safety Marine Traffic Management System and introducing AIS", Journal of Kyeongnam Development Institute, July.

[2] IALA(2002), GUIDELINES ON THE UNIVERSAL AUTOMATIC IDENTIFICATION SYSTEM (AIS) Vol I Part I II, December.

[3] IALA(2002), TECHNICAL CLARIFICATIONS ON RECOMMENDATION ITU-R.1371-1 Edition 1.3, Dec.

[4] IEC 61993-2 (2002), Maritime navigation and radio communication equipment and system - AIS Part2, Dec.

[5] Ministry of Maritime affairs and Fisheries (2002), "2002 statistical year book maritime affairs and fisheries".

[6] Ministry of Maritime affairs and Fisheries(2001), "Pilot Project Report - Introduction of Automatic Identification System".

[7] WS Shim, SH.Suh(2000), "Analysis of requirements for automatic Identification system", Journal of the Korean Society for Marine Environmental Engineering, Vol.3, No.1, February.

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