Evaluation for cargo tracking systems in railroad transportation

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Abstract — Cargo tracking issue on train transportation is challenging area because of long distance haulage, theft, terror attack and customer service. This paper aims at evaluating various cargo tracking systems in terms of cost and technology. The contents of this paper consist of the research trend of cargo tracking system in the railroad transportation and reviewing of technical alternatives in cost and service side. GNSS and RFID are reviewed as location tracking technology, Internet and Satellite technology like INMASAT and Low Earth Orbit are also reviewed as communication infrastructure. This paper selects cost and service factors in two alternatives of GNSS-Satellite and RFID-Internet, among GNSS-Internet, GNSS, Satellite, RFID-Internet, RFID-Satellite and evaluate each alternative in terms of cost and service. In a result, in terms of cost, RFID-Internet type is superior to GNSS-Satellite type, but in service GNSS-Satellite type is preferred to RFID-Internet in point of area coverage and service coverage.

Index Terms — LBS, GNSS, RFID, Train Tracking

I. INTRODUCTION

The railroad transportation is suitable in long distance transport. Comparing with different transport, there is a strong point which is able to secure the timeliness of the freight transportation. However weakness of communication infrastructure, the charge of cargo tracking and trans-shipment to other train make difficulty in cargo tracking. There are many alternatives in cargo tracking system, which is composed of communication and position decision technology. This paper aims at evaluating various cargo tracking systems in terms of cost and technology. The contents of this paper consist of the research trend of cargo tracking system in the railroad transportation and reviewing of technical alternatives in cost and service side. GNSS and RFID are reviewed as location tracking technology, and Internet and Satellite communication technology like INMASAT and Low Earth Orbit are also reviewed as communication infrastructure. This paper selects cost and service factors in two alternatives of GNSS-Satellite and RFID-Internet, among GNSS-Internet GNSS-Satellite, RFID-Internet, RFID-Satellite and evaluate each alternative in terms of cost and service.

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II. BASIC STUDY

A. Feature of rail transportation

Generally speaking, rail transportation has the advantage in price competition compared with other transportation modes under the condition of long haulage. Furthermore as rail transportation has not been affected by weather condition, it can guarantee reliable service to customer in terms of right time and right product. In comparison, rail transportation has also disadvantage in door to door service due to frequent transshipment because it has to operate on fixed rail.

B. Literature review in cargo tracking system

Not so many papers about rail transportation tracking system have been found. H.S. Lee (2003) suggested that there are three type of positioning system, which are satellite based positioning system, mobile communication based positioning system and wireless based positioning system. J.G. Lim et al. (2006) suggested that mobile positioning technology is classified into network based system and GPS receiver based system and hybrid system which combines two types. Y.G. Lee(2003) analyzed cargo tracking system which applied in Korea business. His point is that car monitoring system mixing GPS and GIS technology is shown on high level utilizing mobile networks. In ocean area, vessel monitoring system is developed by MOMAF in order to track Korean flag vessel navigation in dangerous area using GPS and satellite communication technology. Y.S.Byun suggested that multi modal transportation requires cargo tracking system due to the complex structure of transportation in view ownership, position and transshipment. His point is that GPS technology is the popular alternative in tracking transportation object like rail, truck and vessel, but for cargo tracking, special database to link transportation object and cargo is required. T.W. Kim suggested that RFID system is very useful tool to fix position because it make the related information such as identification, passing time and place and frequency of vehicle for related person.

III. REVIEW OF ALTERNATIVES FOR RAILWAY TRACKING

A. Scope of LBS review

In order to review the alternatives, first of all, we have to consider some aspects of rail transportation; that is a cargo train operates on fixed track and cross the border of many countries, and is supplied by electricity. The tracking technology of moving object is composed of location positioning technology and communication technology for position data. GNSS, RFID, ultra sonic wave, infrared are main technology of positioning. In comparison, Internet, power line as wire communication, WMS (Wireless Mesh Network), VHF/UHF, Orbit satellite as wireless communication are main technology for communication.

B. Positioning Technology

There are two kinds of technologies to catch position as reality alternatives among others. GNSS and RFID technology can be listed for rail transportation tracking system. RFID technology can be used as object identification technology and fixing position within closed space. In this review, RFID technology can be considered as fixing position tool utilizing identification technology different from RTLS (Real Time Location System)

1) GNSS

Global Navigation Satellite System is the tracing system which track object on earth using artificial satellite network. For example, GPS by USA, GLONASS by Russia, Galileo Project by EU, Beidou by China and QZSS by Japan can be listed. In reviewing components of GPS, it has three parts which are composed of satellite division, a ground control center, user division. Satellite division had six orbits and twenty four satellites which go round earth on 20,200km height, 55degree of inclination, 12 hour cycle period. The satellites are stationed in order to receive the signal from minimum five satellites. A ground control center is composed of five control stations. The station tracks satellites by GPS receiver and stores distance into database of system. The collected data in the station sent to main ground control center is processed for orbit decision and control of satellite. User division is composed of antenna and receiver. This user system calculates position, speed and time after receiving satellite signal.

Table 1. Types of GPS positioning

Type	Description	Accuracy	Remarks
Single Receiver Positioning	Positioning by single GPS receiver	15-30m 100 meter	Real time based position for navigation Low price receiver
DGPS (Differential GPS)	Combining measuring technology and navigation technology	1-5meter	Requiring reference point and communication media for accurate positioning
Static Survey	Using more than two measurement GPS receiver for accurate positioning	1-5meter	Non real time positioning Requiring reference point High price receiver
RTK (Real Time Kinematic)	Using more than two measurement GPS receiver for accurate positioning in real time	1-2meter	Requiring reference point and communication media for accurate positioning High price receiver

The positioning of GPS is dependent on triangulation method. There are five types of GPS positioning such as single positioning, DGPS, static survey, and RTK(real time kinematic) in accuracy as table 1. Single receiver poisoning type has position error in 15~30meters, but low cost receiver evokes wide usage for navigation. DGPS is designed for improve accuracy limitation in single receiver type. The position accuracy of DGPS is within 1~5meters.

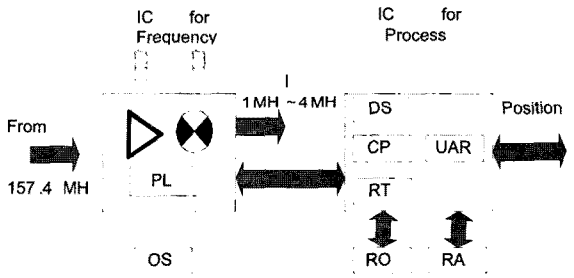

Fig. 1 Block diagram of GPS receiver

Static survey positioning type is also designed for position accuracy combining two measurement GPS as well as DGPS, but it cannot get real time based position. RTK design style is very similar to Static survey type but it has real time based position. Figure 1 shows the block diagram of GPS receiver.

2) RFID

RFID is composed of four components such as RFID Tags, RFID readers, antenna and computer networks. The RFID tag is divided into passive type and active type.

The main difference is that passive tag is activated by RF signal from reader and active tag has its own battery in tag for working. Active tag is more reliable to recognize the signal from distance in succession due to its power rather than passive tag. The signal of active tag

with 915MHZ frequency reaches 30 meters, the signal of active tag with 2.4GHZ frequency reaches 90 meters for identification. Meanwhile, the passive tag has advantage in the size, life cycle and tag cost in comparing with active tag. The tag is smaller and lighter and can be produced in lower cost and last in longer life.

C. Communication Technology

In order to review the alternatives, first of all, we have to consider some aspects of rail transportation; that is a cargo train operates on fixed track and cross the border of many countries, and is supplied by electricity. The tracking technology of moving object is composed of location positioning technology and communication technology for position data. GNSS, RFID, ultra sonic wave, infrared are main technology of positioning. In comparison, Internet, power line as wire communication, WMS(Wireless Mesh Network), VHF/UHF, Orbit satellite as wireless communication are main technology for communication.

1) Internet communication

There are many types of Internet communication which are LAN, WAN, MAN, High-Speed Backbone. In the research, PSTN(Public Switched Telephone Network) or ISP(Internet Service Provider) Network is applied for communication media as a type of WAN(Wide Area Network). There are some kinds of remote access of WAN which are optical cable, xDSL(i.e, VDSL, ADSL, RADSL), frame relay, ISDN, Cable Modem, satellite or cable modem. Among the above access type, cable modem type is preferred as a communication alternative because of lower rental cost and co operation with CATV. In addition, reviewing PSTN of ADSL or VDSL as alternative, we dropped it because of unreliable quality from long distance.

2) Wireless Mesh Network

WMN operates just like a network of fixed routers, except that they are connected only by wireless links. WMNs are gaining significant momentum as an inexpensive way to provide last-mile broadband Internet access. In this application, some of the nodes in the WMN are connected to the Internet via physical wires, while the remaining nodes access the Internet through these wired gateways by forming a multi-hop WMN with them. As deployment and maintenance of physical wires is a major cost component in providing high-speed Internet access9, use of WMN at the last hop significantly brings down the overall system cost and offers an attractive alternative to DSL/cable modem. This technology will be applied in further research to reduce communication fee occurring on each container to send position data to ground control center through satellite.

3) Satellite Communication

A Stationary Orbit Satellite and LEO(Low Earth Orbit Satellite) provide communication channel between ground and satellite. A Stationary Orbit Satellite service is presented by INMARSAT and Low earth orbit is presented by Iridium, GLOBALSTAR, ORBCOMM and ICO. INMARSAT which was found by IMO(International Maritime Organization) is international maritime satellite communication system, whose role is to improve the communication service regarding to ship disaster, safety, maritime public communication, navigation information in anyplace including sea, air and land.

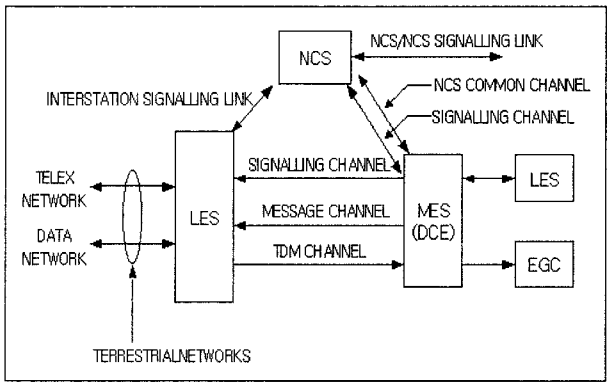

Fig.2 Configuration of INMARSAT-C Transceiver

Figure 2 shows the configuration of INMARSAT-C transceiver. LEO which is suggested by Motorola has some advantages in terms of lighter weight, smaller size, lower power for communication and lower launching cost. This advantage enables for customer to use LEO in field of mobile telecommunication, wireless call service and LBS.

IV. EVALUATION MODEL FOR RAILROAD TRANSPORTATION

In this section, the authors try to set up two types of evaluation model.

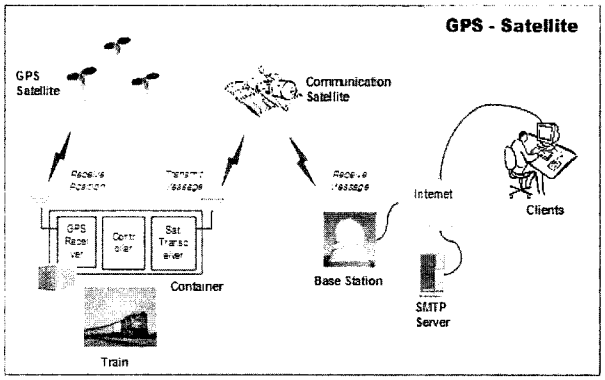

Fig.3 GNSS-Satellite System

The one is the combined type of GNSS and satellite communication (Figure 3)

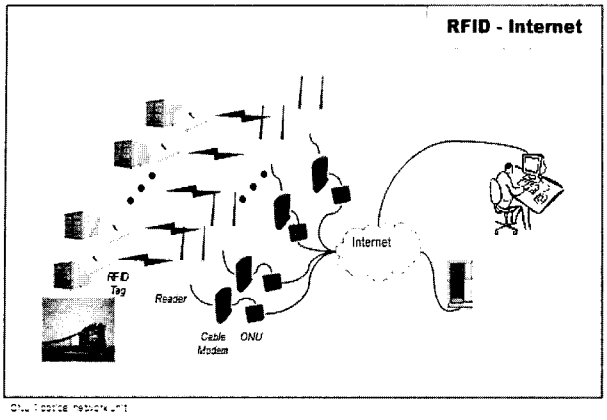

Fig.4 RFID-Internet System

The other is the combined type of RFID and wire communication (Figure 4). Two suggested types here are based proven technology, the applicability reflecting on reality and the trend of technology development.

A. Scenario for Model Evaluation

The authors set up railroad operation from Busan Jin station to Kyung-In ICD near Seoul as the scenario of model for evaluation of two type systems. The distance between origin and destination is estimated to be about 400 kilometers and a train moves average twenty three flat cars and the number of legs per day for Seoul is set to be 24 and for Busan is 22 on real operation. Each container is loaded to be average 23 flat cars per one train and the ratio of 20 foot and 40 foot is set to be 3 to 7 and the full loading ratio to be 80 percent. In case of loading 20 foot container on a flat car, two 20 foot containers can be loaded on one flat car. In order to catch location position of container, GNSS system or RFID system including communication system have to be installed on each container instead of train body. For smooth flow of trains on the track, the train control center is to be installed at O-Bong station near Seoul.

Table 2 Basic Data for evaluation

Number of trains movement per day	For Seoul	24
	For Busan	22
	Total	46
Number of flat cars per train		23
Full ratio per train		80%
Number of container movement per day		1,100 Van
Annually operation days		363 day
Annual container movement		399,300
Number of containers to be installed LBS	Reuse rate is 30%	119,790
Communication frequency	1 report per 2 hours	

The life cycle of control system is set to be five years. For the calculation of total cost on two type model, the related data are summarized on table 2.

B. Evaluation criteria

In order to evaluate two types system, the evaluation criteria has to be selected. Technology reliability, future trend, total cost and service can be listed as evaluation criteria. As the GNSS system and RFID system are proven technology used in practical business, it is reasonable to drop technology reliability as a criteria. After criteria on technology neglected, total cost and service factors remain as evaluation criteria. Considering cost estimation, it is necessary to decide who has responsible for cost, i.e. user or service provider. In this paper, cost estimation on service provider is selected in stead of user's cost. Generally speaking, total cost consists of initial investment and operation cost, but here some items for example personnel cost and overhead cost occurred on center operation which do not give a big difference would be dropped for convenient comparison of two types.

Table 3 Description of Evaluation Criteria

Classifi -cation	Cost		Service	
	Initial Investment	Communi -cation fee	Service Frequency	Coverage of Area
Defini-tion	Hardware development cost including server and communication terminal Software development cost including middle ware and application Hardware	Initial register fee Annual rental fee	Service frequency in considerin g economy aspects and technology aspects	Service boundary
Unit	USD	USD	Hour	Km

As service criteria, response time, service area, installation complexity, law issues like communication frequency allocation are selected, but accuracy of position is dropped as criteria because of train operation. In summary, table 3 is presented as description of evaluation criteria.

V. EVALUATION ON ALTERNATIVE

The result of calculation

1) GPS-LEO

Table 4 Evaluation on GPS-LEO (unit : US$)

Classi-fication	Total cost							Service	
	H/W & S/W cost			Communication fee				Service Frequency	Cover-age
Items	Unit Price	REQ NUM	Total Cost	Items	Unit Price	REQ NUM	Total cost	Real time	All area
server	10,000	2	20,000	Annual rental cost	38	119,790	54,624,240		
application	50,000	1	50,000	Regis-tered fee	15	119,790	1,796,850		
Satellite Terminal embedding GPS	0	119,790	0						
Sub Total			70,000				56,421,090		
Grand Total							56,471,090		

Table 4 shows the result of calculation in GPS-LEO case. In this case, Early investment cost include hardware, software and satellite terminal. The cost of satellite terminal is not added because it is assumed as rent. but communication fee consist of registration fee and service cost including communication and terminal rent fee. As the result, Investment cost amount to USD 70,000 and communication fee to USD 56,741,090. Service frequency is real time and service coverage is all area.

2) RFID-Internet

Table 5 Evaluation on RFID-Satellite

Classi-fication	Total cost							Service	
	H/W & S/W cost			Communication fee				Service frequency	Coverage
Items	Unit Price	REQ NUM	Total Cost	Items	Unit Price	REQ NUM	Total Cost	Time difference between RFID Readers	Within 150 meters
Server	10,000	2	20,000	Annual Rental cost	30	8	2,880		
Applica-tion	50,000	1	50,000	Regis-tered fee	n.a	n.a	n.a		
RFID tag	50	119,790	5,989,500						
RFID Reader	3,000	8	24,000						
Sub Total			6,083,500				2,880		
Grand Total							6,086,370		

Table 5 shows the result of calculation in RFID-Internet case. In this case, initial investment cost includes hardware, software, RFID tag and reader. Annual communication cost for internet is only included as communication cost. As the result, Investment cost amount to USD 6,083,500 and communication fee to USD 2,880. Service frequency and coverage is restricted within RFID reader boundary.

VI. CONCLUSIONS

Cargo tracking issue on train transportation is challenging area because of long distance haulage, theft, terror attack and customer service. There are different set of technology to implement cargo tracking system. Positioning technology and communication technology is main technology part of cargo tracking system. In this paper we suggested two types of alternatives i.e. GPS-satellite and RFID-Internet reflecting on technology reliability and economy aspects. Furthermore, this paper tried to compare cost and service in order to give some guide for implementation. In a result, in terms of cost, RFID-Internet type is superior to GNSS-satellite type, but in service GNSS-satellite type is preferred to RFID-Satellite in point of area coverage, service coverage..

ACKNOWLEDGMENT

This work was supported by the grant No. B0009720 from the Regional Technology Innovation Program of the Ministry of Commerce, Industry and Energy(MOCIE).

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