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DATA TRANSMISSION CAPABILITIES OF THE SHIP'S SATELLITE INTERNET CONNECTION

Streszczenie

Detailed research on data transmission by the ship's satellite Internet connection took place during the sea voyage on a vessel Wilforce. The voyage began in South Korean port of Pyeongtaek, and ended up in Belgian Zeebruge. Collection of data concerning the possibility of transmission by the satellite Internet link was possible thanks to modern communication facilities installed on the ship. Data were analyzed using the available tools of mathematical statistics. The study focused on identifying the bandwidth and transfer speed of both uploading and downloading data from the vessel. The result of the study was to determine the possibility of using the Internet as a medium for the data transmission in e–Navigation.

INTRODUCTION

e–Navigation is a concept developed under auspices of International Maritime Organization (IMO) to enhance safety and efficiency of merchant vessels around the world. It is believed that introduction of e–Navigation should improve efficiency of data management in sea transportation and maritime industry. This emerging concept would also increase security of data exchange in ship–ship and ship–shore connection. The whole process will be fully automatic. Transmitted data should be verified and reliable. The main goal of maritime authorities is to develop a strategic vision for e–Navigation and to integrate all navigational tools, in particular electronic tools. Sub–Committee on Safety of Navigation (NAV) and Sub–Committee on Radiocommunications and Search and Rescue (COMSAR) created special working group engaged in development of e–Navigation strategy and implementation plan. Organizations like Sub–Committee on Standards of Training and Watchkeeping (STW), International Hydrographic Organization (IHO), International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) are also taking active part in creation of e–Navigation concept. In fact IALA is the one who proposed the official definition of e–Navigation [1, 3]:

"The harmonized collection, integration, exchange, presentation and analysis of marine information onboard and ashore by electronic means to enhance berth to berth navigation and related services for safety and security at sea and protection of the marine environment."

Definition was accepted by all the parties involved in creation and development of e–Navigation. It fully describes processes of data flow and emphasized the purposes of data exchanging in sea transportation. There are some voices that this definition is too general and does not contain specific systems or solutions. At present time e–Navigation is rather idea or strategy which is still under construction. Maybe when the work on new concept is finished then somebody will propose new and more detailed definition. Research on e–Navigation is focused on actual user's needs and technological possibilities. Scientists working on the project do not want to close the way for new ideas and propositions. They decided to keep the concept of e–Navigation flexible and adaptable for new technologies and changing requirements. It is believed that these technologies can reduce navigational errors and failures and deliver benefits in areas like search and rescue, pollution incident response, security and protection of natural marine resources, such as fishing grounds and coral reefs. They may also contribute in planning and operation of marine logistics, by providing information about sea, ports and cargos [4, 12, 13].

1. DATA IN E–NAVIGATION

The main tasks of e–Navigation are collection and sharing of data. To ensure the effective implementation of this goals, first of all an appropriate telecommunication structure (both on board the vessels and ashore) have to be created. In the second step safe and efficient data transmission method has to be introduced or chosen from already existing ones. This method must ensure good quality and high speed of data uploading and downloading. The choice is quite wide especially when taking into account the number of ways and methods that allows to connect to the Worldwide Internet Network.

Internet will be the most probable a main medium of transmission in e–Navigation. The rapid development of this technology and availability of all kinds of telecommunication services made the Internet a powerful, flexible and relatively cheap way of communication [2].

2. SHIP SATELLITE INTERNET CONNECTION

Communicating with and between vessels is a necessity, but it is very often difficult and expensive. The first satellite communication systems were developed with one primary consideration – improvement of safety at sea. For the last few years technology has advanced and the requirements for sending data between ship and shore have increased. L–Band services have been the most common communications technology used on–board the ships around the world. Unfortunately these services were very expensive because they are charged per–megabyte. Second option for ship owners was VSAT technology but at the very beginning it was even more expensive than L–Band services. The reason of this was a high cost of the Single Channel Per Carrier (SCPC) technology which was used in VSAT connection (this technology requires dedicated bandwidth for each user). Time Division Multiple Access (TDMA) VSAT networks started a revolution in communications via satellite Internet. New technology offers a comparable service to SCPC networks but sharing and segmenting bandwidth across vessels. High speed, always–on, flat–rate VSAT connectivity came within reach of everyone within the maritime community. Stark Moore Macmillan, professional research company, created a comprehensive survey on maritime VSAT. According to this report the number of VSAT equipped vessel is growing. ”In the past five years TDMA networks in the maritime VSAT market have increased from less than 20% to more than 50%. VSAT operators have provided valuable services to ship owners and operators by delivering always–on, flat–rate, IP connectivity. This has enabled vessels to become highly functional remote offices integrated with corporate network applications. Taking advantage of standard applications has improved vessel management and extends the communications infrastructure to personnel on board, allowing crews to train and remain in contact with home. There has been continuing debate about the complexity of VSAT systems, the drivers to fitting, the costs and the real numbers of ship owners and operators who are actively considering fitting a VSAT system. Despite the increasing profile of VSAT solutions there has never been a major qualitative survey of the maritime market’s attitudes towards, and usage of, VSAT systems.” [7]

2.1. Advantages of Ship Satellite Internet Connection

One of the most common configurations of ship satellite Internet link is so called Multi–WAN routing (Wide Area Network). It allows for diversification of satellite connections depending on current situation and user needs. An example of such configuration is shown in figure 1. In this specific setup one of three connection methods is chosen for each transmission. The choice depends on software which picking up the most appropriate connection at the moment (it takes into account availability, reliability, cost, transmission requirements, bandwidth, speed etc.).

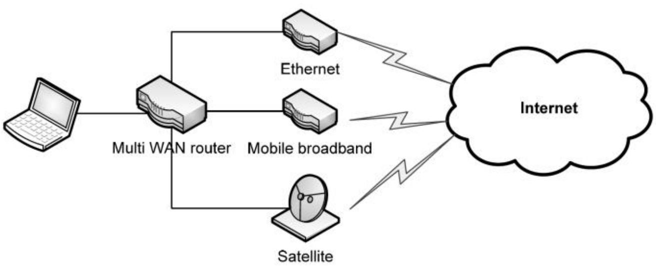

Fig. 1. *Multi Wan router with three different Internet connections.*

Application of above solution enables efficient connection to the Internet. Similar configuration is often used on ships, where not all above options are available all the time. The algorithms applied in Multi–WAN router allows for quick, effective and automatic connection even if some of mentioned methods is not available at the moment. Potential user does not have to understand the whole complexity of the system and these algorithms (there is no need to select or configure the connection method every time). The biggest limitation of presented solution may be transmission costs that vary depending on the chosen connection method. It is worth considering whether is not better to send large packets of data when the ship is closer to the shore and transmission can be cheaper. Router can be configured in many different ways. On programming stage any priority can be chosen. Then the cheapest, the fastest or the most reliable connection will be used. During transmission user has access to information about baud rate, number of data packs sent, transmission costs etc. Connection method can also be selected manually by the user himself. This function can be useful for some services offered in e–Navigation (not all mentioned ways of communication are appropriate for all services, e.g. satellite video conferencing requires large amounts of data transferred and at the moment this cannot be assured by mobile network connection). Another advantage of above configuration is a possibility of diversification for different types of communications (other quality, transmission speed for communication with a higher priority in the hierarchy). This is very important because it allows for high priority communication in distress and during search and rescue operations. Less important communication will be in this cases slowed down or shut down [5, 9].

Internet seems to be one of the best available methods of communication but under one condition. Connection and transmission has to base on a request–response configuration (as in client–server networks). The client requests data from the server, which responds to the request and send appropriate data. This is the way how web sites, e–mail and many other Internet protocols work. Taking into account this limitation Internet is an effective way to obtain required data but only in ship–shore relation. Liaising communication in ship–shore relation by broadcast (multicast) is also possible if we agree on small deception. The data send from ship and obtained by a single land user can be redistributed to other shore users. This gives an impression that data was sent to multiple recipients directly from the ship. This is not exactly multicasting but on the other hand this transmission model is consistent with One Window Concept. An example of this type of transmission can be AIS signal tracking services available on Global Network [8, 10, 11].

High availability and reliability makes Internet the best communication method in shore–shore relation. In land networks, it is common that clients equals servers (they have fixed and known IP). This allows for the use of client–server structure in both directions and for all types of communication. Client is making connections and waiting for the data to be sent e.g. VTS stations connecting to shore AIS systems (such solutions are used in the VTMS stations in the European Union) [8, 10, 11].

2.2. Limitations of Ship Satellite Internet Connection

Despite the fact that Internet connection can be obtained in several independent ways as shown on figure 1, this technology has also some limitations. Internet is an effective way of communication in a client–server type of network, because servers have fixed IP addresses and in most cases known Domain Name System (DNS). Thanks to that client can easily find and connect to the server (if he has appropriate permission and connection to network). Unfortunately it is not so easy to communicate in opposite direction. When server wants to find and connect with client some serious problems arises. The client is rarely available via the Internet due to the following restrictions:

- client has a dynamically assigned IP address,
- local networks are protected by firewalls that blocks incoming calls,
- insufficient number of IP addresses. Network Address Translation (NAT) would be a solution for that problem. NAT assigns private IP for local users and one IP for outside communication.

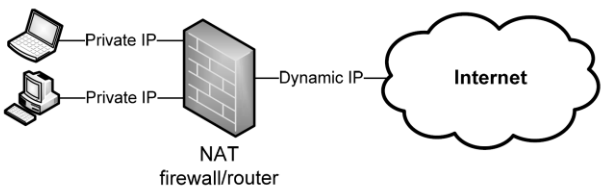

Fig. 2. *Clients with private IP addresses behind NAT router with dynamic IP assigned*

There are no technical obstacles to make each vessel visible and reachable through the Internet (using client–server network topology), but to do this the following steps have to be taken:

- introduction of fixed IP address for all ships or all devices on the ship (this does not allow to use configuration presented on figure 2),
- introduction of a registry of ships and IP addresses / DNS names,
- configuration of router to direct the incoming data to the appropriate hardware.

Unfortunately undertaking the above steps can arise some new difficulties, mainly due to the complexity and administrative requirements of Internet settings. As mentioned earlier Internet has some limitations in terms of data transmission to multiple destinations (multicasting or broadcasting). TCP / IP model has in transport layer a protocol that allows this type of connection (User Datagram Protocol, UDP). However sending data to multiple recipients via UDP is possible only on the local network level, which in no way solves the problem [5, 6].

The ship–ship transmission to multiple recipients is possible when the data are first sent to a server located ashore and then redistributed to final destinations. To some extent it is consistent with One Window Concept, but such communication will not always be effective, e.g. when transmitting ship is within range of land station but recipient is outside this range. There is a belief that other communication systems (other than Internet) may be needed to ensure connectivity in this direction. For many directions and methods of communication the Internet turns out to be not the very best solution. This does not mean that the Internet cannot be used, but other methods of communication may be more appropriate, effective or cheaper.

3. RESEARCH

Detailed research on data transmission speed by the ship's satellite Internet link was carried out during the sea voyage of a vessel named Wilforce. The journey began in the South Korean port of Pyeongtaek, which is located in the province of Gyeonggi. The ship sailed through the South China Sea, Singapore Strait, Indian Ocean and Arabian Gulf to take another cargo in the Qatari terminal Ras Laffan. Then Wilforce proceed through the Gulf of Aden, Bab el Mandeb Strait, Red Sea, Suez Canal and Mediterranean Sea to reach Spanish port of Sagunto in Catalonia (100 nautical miles north of Valencia). After discharging ship sailed via Gibraltar Strait and along the western coast of Portugal, Spain and France and finally arrived to English Channel. Next loading port was Belgian Zeebrugge in vicinity of Brugge. Then the ship cast off with the new cargo and came back on planned route to South Korea. While passing Suez Canal from Port Said to Suez data collection was completed. It began on 10th of December 2013, when the ship sailed from Pyeongtaek, and ended on 10th of February 2014, in Egypt. Detailed route is shown on figure 3. Ship, on which the research was carried out is a gas tanker carrying Liquefied Natural Gas (LNG). She was delivered in September 2013 and is one of the most modern units of this type in the world. She was built in Korean shipyard Daewoo Shipping and Marine Engineering (DSME) for the Norwegian ship owner AWILCO LNG.

On the vessel were installed modern facilities for communication, including VSAT satellite Internet connection. Ship's local network was configured in accordance with ISO 16425 standards. This equipment gave a great opportunity for accurate analysis of data transmission and reception possibilities. Data collection was carried out with freeware licensed BitMeter software running in Microsoft Windows environment. BitMeter is an easy tool to measure the performance of any Internet connection. Download and upload speed is displayed in the form of charts, diagrams and tables. Software calculates some statistics according download and upload speed and saves history of all transfers. BitMeter also informs user if data download limit is exceeded. Program provides detailed statistics on the daily, weekly and monthly use of transfer. In addition BitMeter is equipped with a handy calculator. It allows to calculate the average time of downloading a specific file. It is also possible to compute data amount downloaded in predefined period of time [6].

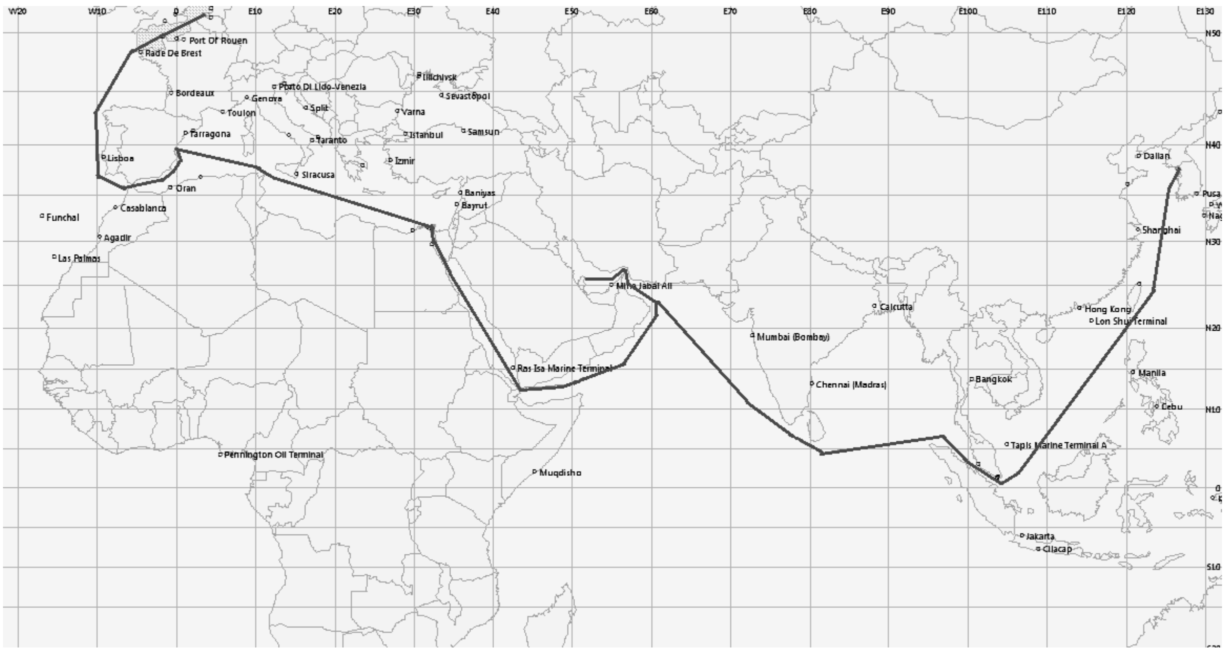

Fig. 3. *Vessel's Wilforce route when collection of data was carried out.*

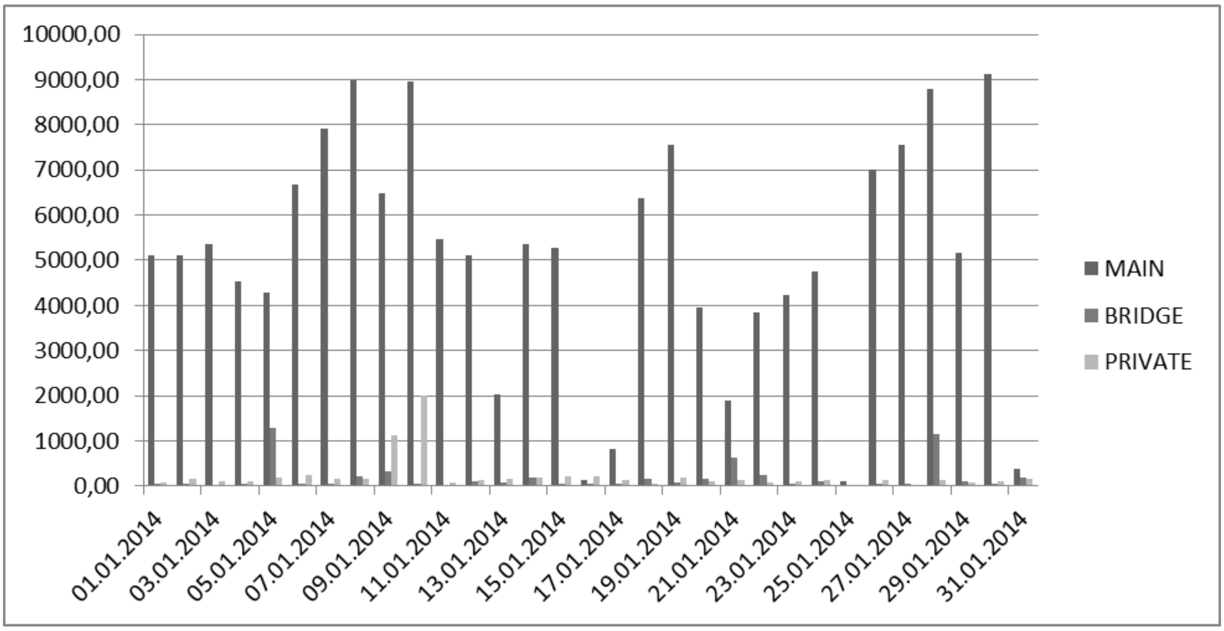

Fig. 3.2. *Diagram showing daily data transfers during period of one month.*

Tab. 1. *Daily data transfers during period of one month.*

	MAIN	*BRIDGE*	*PRIVATE*
MAX	9117,59	1297,45	2013,82
MIN	107,96	27,94	17,33
MEAN	5109,48	183,25	223,47
MEDIANA	5173,05	60,96	133,35
STAND. DEVIATION	2610,51	302,34	381,10
VARIANCE	6814737,09	91410,24	145237,67

Studies were carried out simultaneously on three computers, which for the purposes of this study were called as follows: "MAIN", "BRIDGE" and "PRIVATE". Computer "MAIN" was used for communication with the company, sending reports to land stations (e.g. WETREP sent to Roca Control near the coast of Portugal, and vessel position reports sent to UKMTO during the passage through the Gulf of Aden). It was also used to receive weather warnings, hydro–meteorological forecasts and amendments to charts and navigational publications. The computer named "BRIDGE" as the name suggests was placed on the navigational bridge. Certain transfer restrictions were imposed on this station by the WAN router. It was used generally as the backup computer for “MAIN” and additionally to conduct operational communications and for access to online services such as e–mail and websites. Computer "PRIVATE" was in officer cabin under main deck. It was connected to ship’s local network via wireless distributed throughout the whole superstructure. It was used for routine communication and to access Internet services (websites and e–mail). Link was configured in such

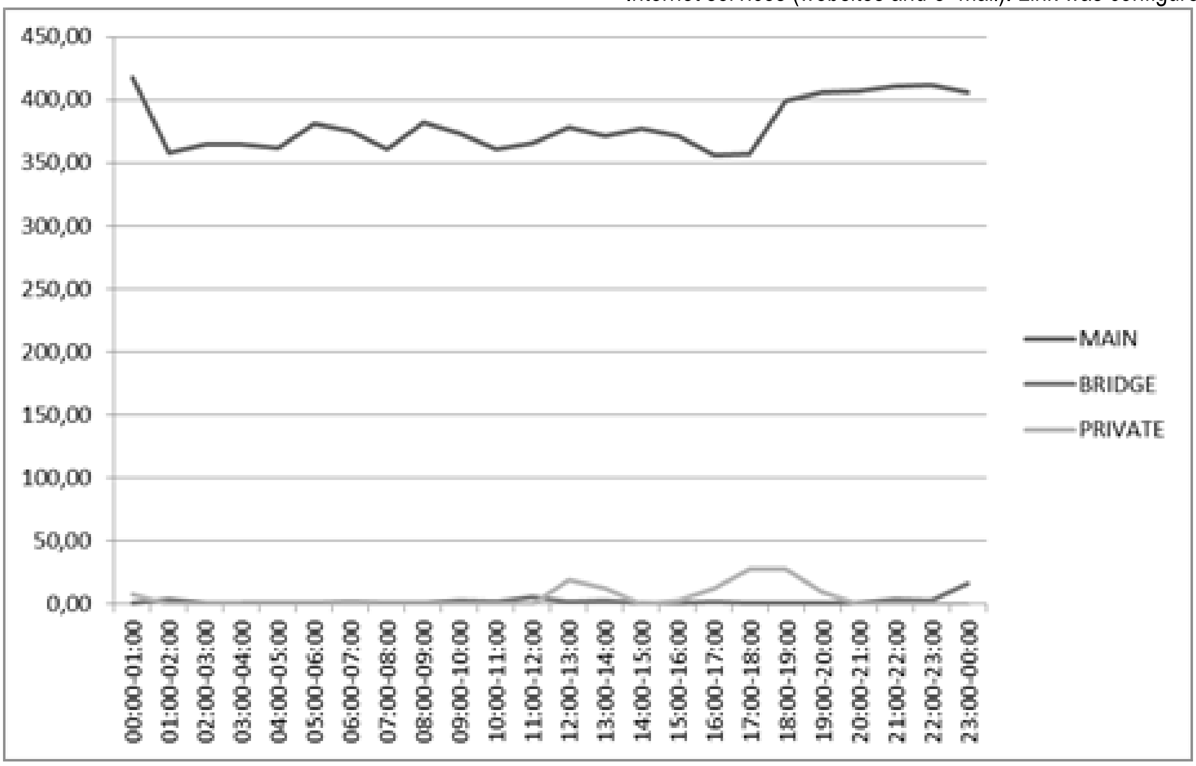

Fig. 4. *Diagram showing hourly data transfers during period of one day.*

way that if computer has not been used, the Internet was disconnected after two hours of inactivity or after exceeding data transfer limits. However this situation never took place during the entire period of this study.

To determine the variability of the data examined, calculated variance was used with the following formula:

$$Var[X]=E[(X-\mu)^2] \quad (1)$$

where:
E is the expected value of a random variable given in square brackets,
μ is the mean value of the variable X.

***Tab. 2.** Hourly data transfers during period of one day.*

	MAIN	*BRIDGE*	*PRIVATE*
MAX	417	17	27
MIN	357	1	0
AVERAGE	380	2	5
MEDIANA	373,9958735	1,198858738	0
STAND. DEVIATION	20,15971399	3,269305374	8,633293927
VARIANCE	406,4140681	10,68835763	74,53376404

Tables 1 and 2 includes standard deviation calculated as the square root of variance. To evaluate the relationship between transfer speed and the time of day or geographical position, statistical tool called correlation was used. Correlation analysis allows to check each pair of measured variables to determine whether this two variables tend to simultaneously change, i.e. whether large values of one variable rather associated with large values of the other (positive correlation) or small values of one variable correspond to rather large values of the other variable (negative correlation), or whether values of both variables are independent of each other (correlation near zero). To check linear relationship covariance was used instead. Covariance allows to check each pair of measured variables to determine whether this two variables tend to simultaneously change, i.e. whether large values of one variable rather associated with large values of the other (positive covariance) or small values of one variable correspond to rather large values of the other variable (negative covariance), or whether values of both variables are independent (covariance near zero). The difference between correlation and covariance is that the correlation coefficients are scaled from –1 to +1 (inclusive) and the corresponding covariance is not scaled. Variation coefficient, like the correlation is a measurement of the extent to which the two measurement variables may differ from each other.

CONCLUSIONS

Research outlined the difference in data transmission between 'MAIN' (higher priority) and other two computers. During the study period there were also temporary problems with an Internet connection. Data collected by BitMeter indicated that the congested Internet link slowed down. In order to avoid this situation in the future router rules have to be programmed in a different way. The most important conclusion from the study is that the speed of onboard Internet is sufficient medium to be used in e–Navigation. It must be assumed that it should be configured as a computer with the highest priority (MAIN). In this case, both the average and median values seem to be more than satisfactory. However, high value of standard deviation for month is a little bit disturbing. Hourly deviation in the scale of one day is not so large in relation to the amount of transmitted data. Probably this situation was caused by transmission problems arising in the second part of the month. Low amounts of incoming and outgoing data caused an increase in the standard deviation. Additional examinations should explain these inconsistencies. Attempts to correlate transmission speed with the ship's position also gave an interesting results. Data collected shows that the transmission speed is slightly correlated with geographic position, in particular with the latitude. This may result from antenna's elevation when vessel approaches the equator. VSAT satellite, on which the Internet link transponders are fitted, it is a geostationary satellite placed above the equator. There is also a certain relationship between a transfer rate and the time of the day. It may be caused by atmospheric propagation characteristics different depending on the altitude of the sun and the weather. It may also be associated with different activity of users. Both, correlation of data transmission with the ship's position and with time of day requires additional research to assess whether the relationship is significant or it is within the borders of statistical error.

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BADANIE MOŻLIWOŚCI TRANSMISJI DANYCH PRZEZ STATKOWE SATELITARNE ŁĄCZE INTERNETOWE

Streszczenie

Szczegółowe badanie transmisji danych przez satelitarne łącze internetowe odbyło się podczas rejsu statkiem Wilforce. Podróż rozpoczęła się w południowokoreańskim porcie Pyeongtaek, a zakończyła w belgijskim Zeebruge. Nowoczesne urządzenia do prowadzenia stałej łączności, zainstalowane na statku, pozwoliły na zgromadzenie danych dotyczących możliwości transmisji danych przez satelitarne łącze internetowe. Dane zostały poddane wnikliwej i dokładnej analizie z wykorzystaniem dostępnych narzędzi statystyki matematycznej. W badaniach skupiono się na określeniu przepustowości łącza i prędkości transferu zarówno ze statku, jak i na statek. Wynikiem badań jest ocena możliwości wykorzystania Internetu jako medium transmisji danych w e–Nawigacji.

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