Desain dan Analisis Hybrid Vessel Monitoring System berbasis Kolaborasi DTN dan Internet

Design and Analysis of Hybrid Vessel Monitoring System based on DTN and Internet Collaboration

Akbari Indra Basuki[1], Aciek Ida Wuryandari[2]
[1]Research Center For Informatics, Indonesian Institute of Sciences, Bandung, 40135, Indonesia
[2]School of Electrical Engineering and Informatics, Bandung Institute of Technology, Bandung, 40132, Indonesia
Email: akbari@informatika.lipi.go.id

_____

Abstract

In this paper, we propose hybrid Vessel Monitoring System (VMS) design as alternative for current VMS scheme by collaborating internet connection and Disruption-Tolerant-Networks (DTN). The hybrid solution combines offline VMS that use radio networks and online VMS that utilizing satellite-based internet. Hybrid VMS aims to provide a more flexible VMS design and able to speed up delivery process of offline vessel's data. The concept is both type of vessels must install a standard radio for DTN backbone network. This backbone network is used to speed up data delivery by forwarding VMS data from one vessel to another using DTN forwarding scheme. Data can be forwarded to other offline vessels that will return to harbor earlier or to online vessels which have internet connection. Performance measurement is done through simulation analysis using ONE simulator. It aims to measure the speed up data delivery using hybrid VMS implementation compare to a pure offline VMS implementation. Simulation result show that hybrid VMS able to speed up data delivery for offline vessel data in 1.5 up to 2 times faster compare to a pure offline VMS implementation. Hybrid VMS also has advantages in flexible implementation by easily switching between online and offline VMS scheme, according to fisherman financial situation. Spray-and-Wait routing is the most suitable routing algorithm for hybrid VMS according to the efficiency ratio.

Keywords: Vessel Monitoring System, Hybrid VMS, DTN, data delivery speed up, Internet collaboration

Abstrak

Pada makalah ini, diajukan skema alternatif untuk _Vessel Monitoring System_ (VMS) yang disebut _Hybrid_ VMS dengan mengkolaborasikan jaringan internet dan _Disruption-Tolerant-Networks_ (DTN). Solusi hibrida ini menggabungkan skema _offline_ VMS yang menggunakan jaringan radio dan _online_ VMS yang menggunakan jaringan berbasis internet satelit. _Hybrid_ VMS bertujuan untuk menyediakan alternatif skema VMS yang lebih fleksibel dan mampu mempercepat waktu pengiriman data pada kapal yang tidak menggunakan perangkat _online_ VMS (_offline_ vessel). Pada skema _Hybrid_ VMS, kedua jenis kapal, baik yang menggunakan _online_ VMS maupun _offline_ VMS, sama-sama memasang perangkat radio yang sama untuk digunakan sebagai jaringan dasar DTN. Jaringan dasar DTN ini digunakan untuk mempercepat pengiriman data VMS pada _offline vessel_ dengan cara mem-_forward_ data VMS ke sesama _offline vessel_ yang akan kembali ke pelabuhan terlebih dahulu atau ke kapal lain yang memiliki perangkat _online_ VMS (_online vessel_). Pengukuran performa pengiriman data dilakukan dengan mensimulasikan skema _Hybrid_ VMS menggunakan simulator ONE dan membandingkannya dengan skema _offline_ VMS murni. Hasil simulasi menunjukkan bahwa _Hybrid_ VMS mampu mempercepat pengiriman data _offline vessel_ sebesar 1.5 kali sampai 2 kali lebih cepat. _Hybrid_ VMS juga memiliki kelebihan dalam hal fleksibilitas implementasi di lapangan. Nelayan dapat dengan mudah untuk berganti dari mode _online_ VMS ke _offline_ VMS menyesuaikan kondisi keuangan masing-masing. Algoritma _routing_ DTN yang paling sesuai untuk skema _Hybrid_ VMS adalah _Spray and Wait Routing_ karena memiliki efisiensi rasio yang bagus.

Kata kunci: _Vessel Monitoring System, Hybrid VMS, DTN,_ pemercepatan pengiriman data, Kolaborasi dengan Internet

_____

1. Introduction

Vessel Monitoring Systems (VMS) is a monitoring system for fishing ships activity that aim to manage and regulate fishery activity. VMS usually use satellite-based internet connection as its main communication system [1]. Large fishery industries have not any problem to implement

VMS. However, for small and medium fisheries, VMS deployment is a real burdensome. Not only the price rate of VMS devices is so expensive but their operational cost too. In addition, some small fishery communities argue that VMS device have not any direct impact for them, especially for their fishing activity. They believe that VMS is only beneficial for government [2].

Several researches have been conducted to overcome the financial problem of VMS device by proposing an alternatives solution of VMS based on radio modem [2] and GSM/GPRS connection [3]. The proposed VMS devices store data position internally on VMS devices and its only being deliver to Fishery Monitoring Center (FMC) once they arrived in harbor. In the harbor, there is a gateway node which acts as a bridge to forward the data to FMC server. This solution is referred as offline VMS. Offline VMS successfully overcome operational cost problem and make VMS affordable for any size of fishery industries. Unfortunately, this solution also creates a new problem called as high latency delivery. Fishing ships usually sail for a week up to a month. If VMS data only can be transmitted to FMC server when the vessels arrive in harbor, there will be unacceptable long delay (1 week – 1 month). Data may still have advantages for statistical analysis but not for monitoring usage.

In this paper, we propose a hybrid VMS solution based on online VMS and offline VMS to coexist and cooperate together in a single VMS solution. Both previous VMS have their own key point. Online VMS have its real time update property. In other hand, radio-based VMS or offline VMS has its deployment scalability to be installed in any size of vessel. Mixing up the key point of both VMS will result in high scalability deployment with near real time data update improvement. The idea of Hybrid VMS is all vessels must install radio-based modem as the basic communication devices for Disruption-Tolerant-Networks (DTN) forwarding mechanism. In addition, several vessels, usually large vessel, also use additional satellite based modem for real time update. Small vessels will speed up data delivery by forwarding VMS data to large vessel which have satellite-based internet connection. Data delivery does not only occur in harbor but anytime on the sea when small vessel meet and communicate with large vessels. In a worse scenario, when small vessel never meet large vessel on the sea, delivery latency still can be shorten by forwarding data to other small vessel which will return to harbor earlier.

In this research, we use DTN as a backbone network for Hybrid VMS. Every node can deliver VMS data to Fishery Monitoring Center (FMC) by forwarding the data to all or some other nodes they encounter. By doing so, the vessel and FMC must not meet each other to communicate. A small vessel may be never meet with large vessel, but by forwarding the data to others small vessels, data will be able to reach large vessels and delivered to FMC server. DTN also have convergence layer to accommodate the utilization of two or more network devices in one system. Large vessels can use radio-based and satellite-based modem concurrently and act as a gateway node. The other reason is DTN is also proven to have better performance compare to conventional networks in maritime environment [4, 5].

In previous research, hybrid network based on DTN is commonly used to reduce internet data traffic [6]. Data traffic can be shared by using DTN, so that the traffic load in mobile operator's network infrastructure can be reduced. The focus of previous research is to maximized delivery ratio of the message so that it can be used as alternative to deliver message and reduce the heavy load of network infrastructures.

In this study, we use DTN-based hybrid network to speed up data delivery when network infrastructure is not exist. Our focus is to shorten the delivery latency, so the data can be sent to FMC server as soon as possible. Delivery ratio is not our focus because Hybrid VMS can guarantee 100 % data delivery. All vessels will preserve their own data in internal storage until they return to harbor. If some data lost in routing process, there will be exact copy of data in the sender node. Performance testing is conducted by simulating Hybrid VMS design in ONE simulator [7].

The coordination of this paper are followed. In chapter two, DTN principle will be described. Chapter three discuss about Hybrid VMS design and its simulation model. Chapter four present theoretical and simulation analysis. The conclusion is presented in chapter five.

2. Disruption-Tolerant-Networks

2.1. DTN principle

Delay-Tolerant-Network (DTN) is a connectionless network. Every source node is able to communicate with destination node without meeting each other. This capability is achieved using Store, Carry and Forward (SCF) method. Intermediate nodes take a role as a relay node to transmit data between source node and destination node (Fig. 1).
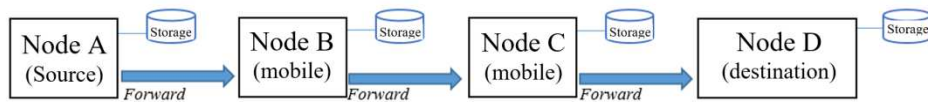
Figure 1. Store-Carry and Forward method in mobile DTN

SCF method is implemented using additional protocol layer called bundle layer. This bundle layer is placed on the top of transport layer. This design will give flexibility to choose the suitable transport layer protocol. DTN can be implemented using TCP or UDP protocol. Bundle layer also act as overlay layer. The specifications of bundle layer are similar for any node, but the specification for lower layer may be different according to the environment and appropriate condition. To implement this design, some of DTN nodes will act as gateway nodes. Gateway nodes have two or more different lower layer specification at once. Gateway nodes have convergence layer which is used to collect data from several network interface.

DTN utilize ad Hoc networks for its basic communication scheme. Each node communicates directly with another node within radio range. In mobile DTN, nodes move freely in random pattern. They organize themselves in instance each time they meet one another. Hence, network topology change rapidly and unpredictable. The topology of the networks will change immediately when each node start to move on its own direction. SCF method has advantages in this condition, since they are not affected by the changing of network topology.

2.2. DTN routing algorithm

There are two general kinds of routing algorithms, they are flooding-based method and forwarding based method. Routing algorithms which use flooding-based method, replicate bundles to some or every other node that they encounter. In epidemic routing algorithm, every bundle always being copied to another node, except the bundles which is already exist. Before each node exchanges their bundles, they exchange summary vector which contain information about the bundles ID. The ID is used to check which messages are not in possession and then it will be exchanged between the communicating nodes [8]. Spray and wait routing only send N copy of data to minimalize resource consumption in epidemic routing. The sender only transfer the data and one copy permission to first N node they encounter. Then the receiver nodes only forward the data to the destination node. In binary mode, the number of copy permission is divided equally between communicating node. The sender and receiver will have same number of copy permission, ½ N. When each of those nodes meets with the other nodes, all of them will carry ¼ N copy permission [9].

In forwarding-based method, the bundle sends to another node based on network information. Therefore, routing algorithm has internal computation parameter to decide which nodes is the best to deliver the bundles. Prophet routing use probabilistic and transitivity analysis to define the best node which have the highest probability to transfer bundles to destination node. Prophet routing consider that nodes will move in non-truly random pattern. Hence, the history encounter will have great information about network structure [10]. The most commonly implemented routing algorithm is flooding/epidemic routing and spray and wait routing.

3. Hybrid Vessel Monitoring System

3.1. Hybrid VMS design

Hybrid Vessel Monitoring System (Hybrid VMS) design is presented in Fig 2. Hybrid VMS combine the design of online VMS and offline VMS into a single system. Online VMS is represented by green nodes and use satellite based internet communication (orange lines). Offline VMS use radio networks (red lines) and represented as white node. In Hybrid VMS, both vessels install same radio device for data forwarding between vessels. Green nodes (online vessel) also install radio networks to communicate with the white nodes (offline vessel).

In online VMS, the green nodes use satellite based internet connection to deliver data to FMC. In Hybrid VMS scheme, the green nodes also act as a gateway node to shorten data delivery for white node by providing direct link to FMC using satellite based internet.
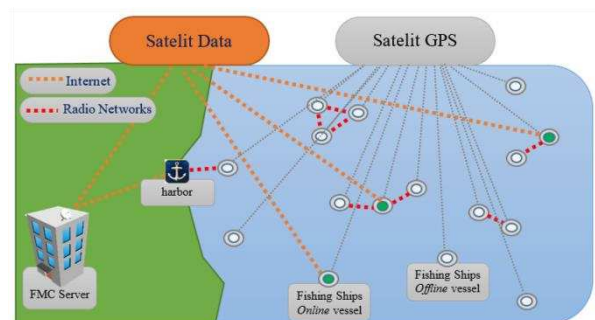

Figure 2. Hybrid Vessel Monitoring System design

In offline VMS, the white nodes only use radio communication device. They can deliver data to FMC if they return to harbor. In Hybrid VMS scheme, they can deliver data to FMC by forwarding their data to another white node which

will return to harbor earlier or to the green nodes which have satellite-based internet connection. Theoretically, HVMS performance will stand between online VMS and offline VMS performance. The best HVMS performance is equal to online VMS but the worst performance is equal to offline VMS.

3.2. Hybrid VMS performance measurement

Hybrid VMS performance testing is conducted by means of simulation analysis. The analysis is done by comparing the simulation result with theoretical analysis and also with currently available VMS scheme. In this subsection, simulation model and theoretical analysis of Hybrid VMS is presented.

3.2.1. Simulation model

Simulation models cover environmental models, nodes models, movement models and communication models. The chosen environment is Province of Kepulauan Riau, Indonesia. Environment model refers to fishing ships density and its variation during different fishing season. Density of fishing ships (DL) can be measured by dividing fishing ships availability (N) in the surrounding area with sea area (AL) (1).

$$D_L = \sum_{i=1}^{n} N_i \bigg/ A_L \qquad (1)$$

In normal condition, it is assumed that the minimum number of fishing ships which is sailing concurrently is 75 % of all available fishing ships. In high tide season, only large fishing ships which have capacity more than 100 Gross Ton (GT) that remaining to sail. Based on the data provided by Ministry of Marines and Fisheries [11] their average number in all Indonesian area is 25 % from the population.

Nodes model in this simulation refers to fishing ships which have capacity more than 30 (GT). This kind of fishing ships is capable to sail on overall Indonesian sea. Hence, they are obliged to install VMS devices. Unfortunately only few of this vessel which have install online VMS devices. Based on [11], online vessel population is ranging from 10 % up to 43 % from the total population. In this simulation, we use minimal number (10%) to measure the minimal impact of using online vessel for Hybrid VMS in overall Indonesia sea area.

The movement of the ships is unpredictable and dynamic. They usually search for fish based on natural sign or their own judgments. After founding fishing spot and stayed several hours to fish, fishing ships will begin to move and searching for new fishing spot. This behavior can be modelled as Random Waypoint Movement model (RWPM). In RWPM, mobility of a node is started by choosing a certain place randomly as a destination point. Direction angle is calculated based on starting coordinate and destination coordinate. When a node arrives at destination point, it will stop at certain time before it chooses another destination and start to move again [12].

All vessels or fishing ships will return to harbor or fish auction center to dock and unloading the fish. In this simulation we use mobility chain model to accommodate this behavior. Mobility chain model is constructed by adding Return to Home Movement model (RTHM) after RWPM. This transition is occurred when fishing period is over and fishing ship heading back to auction center or harbor. RWPM represent sailing behavior and RTHM represent vessel movement of returning to harbor and docking on it. The initial state of each vessel is divided proportionally for those two phase (Fig. 3). Fishing period is in one week period. This value refers to minimum sailing period of fishing ships. It consists of 1 days of docking phase and 6 days of sailing phase.
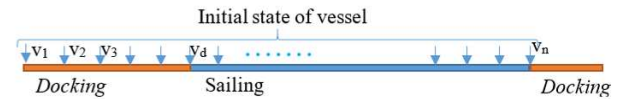

Figure 3. Distribution of vessel's initial state

Network devices used in this simulation is Xbee Pro 900HP model. It was chosen as our model because it has stable performance in various acceptable node density [13]. The size of VMS data is small (≤ 1 KB). However, delivering VMS data using SCF method potentially make a heavy load to the networks, since every node not only store and forward their own data but also another node's data. To overcome this problem we compare Epidemic routing algorithm and Binary Spray and Wait (BS&W) routing algorithm performance to analyze their network constraint limit and to determine the most suitable routing algorithm.

3.2.2. Theoretical analysis

In offline VMS scheme, VMS data can be forwarded to FMC after fishing ships arrived in harbor. Fishing ships sailing period is denoted as SP and VMS data is generated in Generation Time (GT) after departure. The delivery latency of the VMS data of offline VMS then can be formulated as in (2). Where TtH is Time to Harbor. TtH values are varies according to sailing distant between vessel and the nearest harbor/auction center.

$$T_{offlineVMS} = (SP - GT) + TtH \qquad (2)$$

In online VMS, VMS data is sent to FMC regularly in certain interval called as Update Time (UT). The UT value range from 15 minute up to 1 hour [1]. Compare to offline VMS scheme that

require a week up to a month of sailing delay to deliver data, there are a big gap between both schemes. DTN provide win-win solution for both scheme by cross forwarding VMS data between vessels, whether the vessels are implement offline or online VMS.

Hybrid VMS delivery performance can be described as follows. If the vessel implement online VMS scheme, VMS data will be delivered instantly to FMC in UT period. If the vessel implements offline VMS scheme, their VMS data can be speed up as follows.

- If the vessel meets online vessel, then Delivery Time (DT) = TT_G + UT, where TT_G is the delay between the time data is generated until the time vessel meet with gateway/online VMS.
- If the vessel only meets with another offline vessel, then Delivery Time (DT) = TT_V + TtH_V, where TT_V is interval between the time data is generated until the time vessel meet with another offline vessel. TtH_V refer to Time to Harbor of another offline vessel that being encountered.
- If the vessel never meets with another vessel whether it was offline or online vessel, then delivery performance is same as in offline VMS scheme (2).

The summary of hybrid VMS delivery latency is described in (3). The "Min()" function determine the most minimum time taken by the available delivery options.

$$T_{hVMS} = \begin{cases} UT & , if\ online\ vessel \\ Min \begin{pmatrix} TT_G + UT, \\ TT_V + TtH_V, \\ (SP - GT) + TtH \end{pmatrix}, if\ offline\ vessel \end{cases} \quad (3)$$

4. Simulation analysis

4.1. Simulation result

ONE simulator simulates hybrid VMS performance in comparison with offline and online VMS. The simulated scenario is based on the models that described in section 3.2. As comparison, routing algorithm that being used by Hybrid VMS is Binary Spray and Wait Routing (BS&W) and Epidemic Routing. The performance is stated as accumulative delivery probability of VMS data along fishing period. Hybrid VMS simulation result is shown in Fig. 4 and its theoretical analysis, based on section 4.1, is described in Fig. 5.

Delivery probability of Online VMS at update time (UT) is always 100 %. Because every online vessel has internet connection, VMS data can be forwarded to the FMC in real time.

In offline VMS, because of the initial state of vessel distribution (Fig. 3), there are constantly d-number of vessel from all of n-number of vessel that always docking in the harbor. Therefore, the

lowest delivery probability of offline VMS at constant UT is always higher than (d/n) %.

The result of simulation also has same performance as the theoretical analysis. Based on subsection 3.2.1, docking time (d) = 1 days and sailing time (s) = 6 days, so d/n = 1 / (1 + 6) % = ±14 %. The minimum delivery probability of offline VMS at UT must be higher than 14 % and based on simulation result, the value is also higher than 14 %.
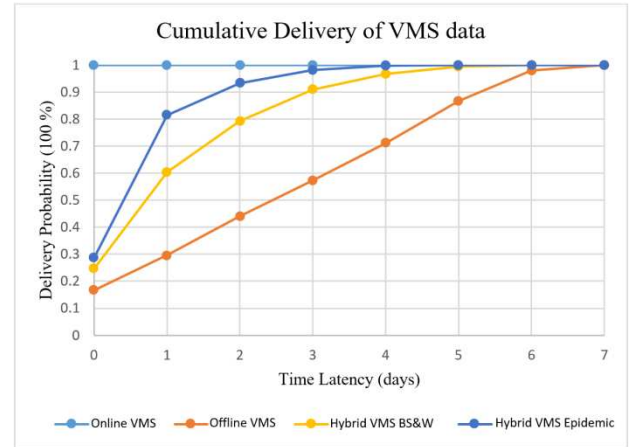

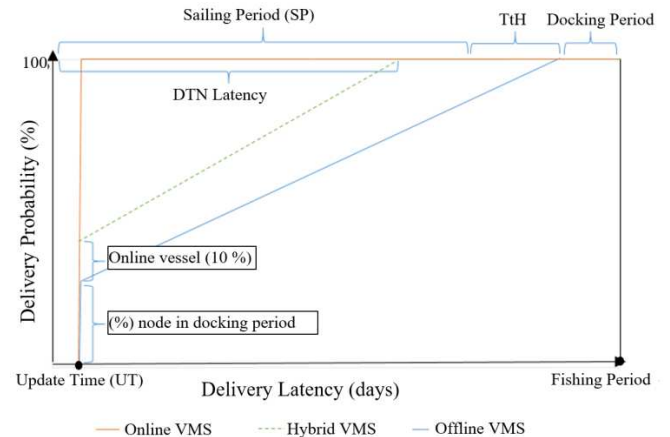**Figure 4.** Hybrid VMS performance based on simulation result

Figure 5. Hybrid VMS performance based on theoretical analysis

Based on theory, hybrid VMS performance stands in the middle of offline VMS and online VMS and it is proven in simulation result (Fig. 4). Hybrid VMS use DTN scheme, so its delivery probability is heavily affected by the density of the networks. In high density networks, there is a bigger chance for each vessel to meet and interact with the others. Hence, DTN forwarding mechanism can work well and increase delivery probability of VMS data significantly. However, because the width of the sea, vessel distribution is very sparse and some vessel may have distinct fishing route that isolating them with the others. As consequences, their data cannot be transferred to FMC faster in reason of they never encounter others vessel to forward VMS data. This

phenomena slow down data delivery completion and turn hybrid VMS performance into logarithmic like curvature.

As shown in Fig 4, in Epidemic routing-based Hybrid VMS, it is only take 2 days to transfer more than 90 % of VMS data, but it require 2 days more to achieve 100 % of data delivery completion. The similar result is also shown by Binary-Spray and Wait routing solution. It requires 3 days to transfer 90 % of data but it is also require 2 days more to complete all data delivery. Overall, hybrid VMS solution has better performance compare to a pure offline VMS solution. In 98 % delivery probability, epidemic routing-based hybrid VMS scheme is able to speed up data delivery in twice faster (3 days compare to 6 days in a pure offline VMS solution). In 100 % delivery probability, hybrid VMS speed up performance is 1.5 time faster than offline VMS scheme.

The interesting part in this simulation is the simulation only use the minimum number of online vessel availability (10 % of total vessel population). Based on [11], some sea areas have higher number of vessel. For example, 43 % of vessel in Java Sea is potential online vessels. Data delivery will increase significantly if all of those vessels take part as online vessel and use hybrid VMS scheme.

4.2. Internet collaboration effect

Based on simulation result, a small amount of internet connection (10% population is online vessel) is able to increase delivery performance significantly. However, online vessel existence in certain sea area is unguaranteed. Therefore, internet utility effect needs to be analyzed so that overall system performance can be predicted if online vessels are absent. Internet collaboration effect can be analyzed by comparing Hybrid VMS scheme with a pure DTN-based VMS scheme. In a pure DTN-based VMS, all vessels are offline vessel so that data delivery is only occurred between offline vessels. The comparison result is shown in Fig. 6.

According to the result, Internet utility only increases delivery probability of VMS data but not for their completion delivery. Completion delivery is determined by all vessels. If one/some vessels have distinct route that isolated them with the other vessels, internet utility also unable to affect data delivery process. In the first day, Internet utility increase data delivery in 33 % faster, achieving 60 % data delivery only in one day. This value is not constant and may vary based on online vessel density and movement. In average, internet collaboration effect is able to speed up data delivery in approximately a half day period.
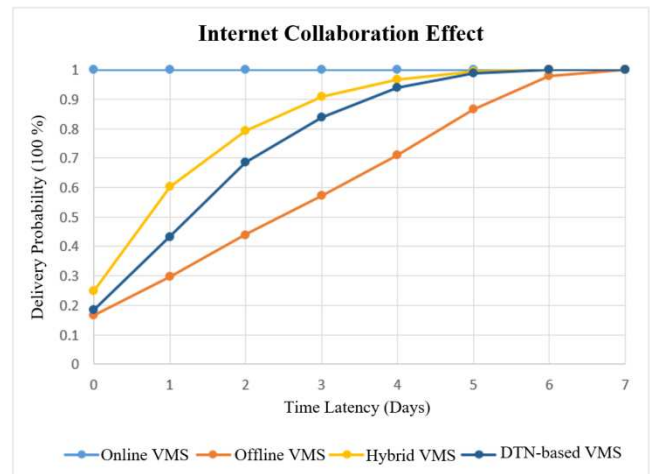

Figure 6. Internet collaboration effect in Hybrid VMS

4.3. Flexibility of Hybrid VMS

Hybrid VMS has another advantage in providing more flexible VMS solution. Online VMS scheme only use internet-based satellite communication and does not provide any other alternative. When a vessel's owner have financial crisis and cannot afford satellite-based internet subscription fee, whether it is caused by decreasing number in the catchment or the rising of fuel price, the vessel will not able to send their VMS data.

In hybrid VMS, if an online vessel owner have financial crisis, they will switch their communication networks to use radio networks only and disable the satellite based internet. In this state the vessel will act as an offline vessel and capable to send VMS data to FMC using DTN forwarding scheme. As consequence, the number of online vessel will decrease due to this switching mechanism. However, since online vessel effect is only accelerating data delivery but not affecting delivery completion in total (subsection 4.2), this switching mechanism still guarantee data delivery for the switching node.

Hybrid VMS design does not only guarantee VMS data delivery for all vessels but also prevents the fisherman reluctances from using VMS device because of financial reason. Government permission is very crucial for this method to prevent irresponsible switching procedure by the fisherman. As for example, the switching procedure is only permitted before the sailing departure of vessel and under local government approval.

4.4. Routing algorithm efficiency

Hybrid VMS use DTN forwarding scheme as its backbone network. Because DTN system uses SCF method, every vessel is not only forwarding and carrying its own data but also another vessel data. This condition possibly creates high constraint in

storage and communication resources. Hence, DTN routing algorithm needs to be selected carefully. Based on subsection 3.2.1, routing algorithm that being tested is Binary Spray and Wait (BS&W) routing and Epidemic routing.

The most suitable routing algorithms can be defined by calculating its efficiency value. Efficiency value is formulated by dividing the real utilization of DTN forwarding scheme (SCF method) with the total overhead ratio of DTN networks.

SCF method utilization determines how often this method is being used by every node in the hybrid VMS network to deliver data to FMC. Utilization under 100 % means there are some data that unable to be sent using SCF method. In this case, data is kept by the generator node until it is arrived in the harbor. In general, SCF method utilization value indicates the performance of routing algorithm to deliver data using DTN forwarding scheme. Based on subsection 3.2.1, fishing ships/node is divided into two phase, docking phase and sailing phase. In docking phase the node is able to deliver data to FMC directly using internet connection in harbor. This nodes use direct delivery method rather than SCF method. Therefore, in reality the maximum possible number of nodes that using SCF method (SCF_util$_{max}$) is limited to sailing nodes only. Based on (4), their number is 6/7 % or 85.71 % of total nodes. Real utilization of SCF method is acquired by dividing total SCF method utilization by all nodes in network (SCF_util$_{total}$) with the maximum possible utilization of this method (SCF_util$_{max}$) (5). Based on simulation result, total SCF_method utilization value of each routing algorithm and its conversion to real SCF_method utilization value is shown in Table 1.

Table 1. Routing algorithm efficiency

Hybrid VMS Configuration	Total SCF Method Utilization (%)	Real SCF Method Utilization (%)
HVMS BS&W_10 copy	60.88	71. 62
HVMS Epidemic	81.47	95.85
HVMS BS&W_50 copy	79.82	93.91

Overhead ratio determines how many other nodes are used as relay nodes to forward data (6). This value determines how much the overhead is occurred in the network that use DTN concept. In end-to-end connection such as internet, overhead ratio value is zero, because the forwarded data is also the data that being delivered. In simplest form of DTN network, when data is sent from node A to node C, via node B, the overhead ratio value is 1,

because the data is forwarded twice (via node B and C) and data is only delivered to node C. Total overhead ratio is found by multiply average overhead ratio with number of nodes in the networks (7).

$$Sailing\ node = \frac{(Sailing\ period)}{(Docking\ period + Sailing\ period)} * N \quad (4)$$

$$Real\ SCF_{method_{utilization}} = \left(\frac{SCF_{util_{total}}}{SCF_{util_{max}}}\right) * N \quad (5)$$

$$Overhead = \frac{Data_{forewarded} - Data_{delivered}}{Data_{delivered}} \quad (6)$$

$$Total\ overhead\ ratio = average\ Overhead\ ratio * N \quad (7)$$

$$Efficiency = \frac{Real\ SCF\_method\_utilization}{Total\ overhead\ ratio}$$

$$Efficiency = \frac{\left(\frac{SCF\_util_{total}}{SCF\_util_{max}}\right) * N}{average\ Overhead\ ratio * N} \quad (8)$$

Table 2. Routing algorithm efficiency

Hybrid VMS Configuration	Real SCF Method Utilization (%)	Average Overhead Ratio	Efficiency
HVMS BS&W_10 copy	71. 62	4.2	17.05 %
HVMS Epidemic	95.85	99.22	0.97 %
HVMS BS&W_50 copy	93.91	14.86	6.32 %

Based on the previous description of real SCF method utilization and total overhead ratio, efficiency value can be formulated as in (8). Based on simulation result, efficiency value of each routing algorithm, is shown in Table 2. According to the table, the most suitable routing algorithm is spray and wait routing, since it have better efficiency value (17.05 %) compare to Epidemic routing (< 1 %).

Despite epidemic routing has better delivery performance which is reflexed by its higher SCF method utilization, Binary Spray and Wait (BS&W) routing is still better choice. BS&W performance can be increase further by doubling its copy permission number. Based on Table 2 and Fig. 7, BS&W Routing algorithm with 50 copy permission have similar result compare to Epidemic Routing in term of delivery performance and Real SCF_method utilization value. However, BnSW routing have advantages in lower overhead ratio. This result show that BnSW routing algorithm is better choice for Hybrid VMS scheme due its high delivery performance and low overhead ratio.
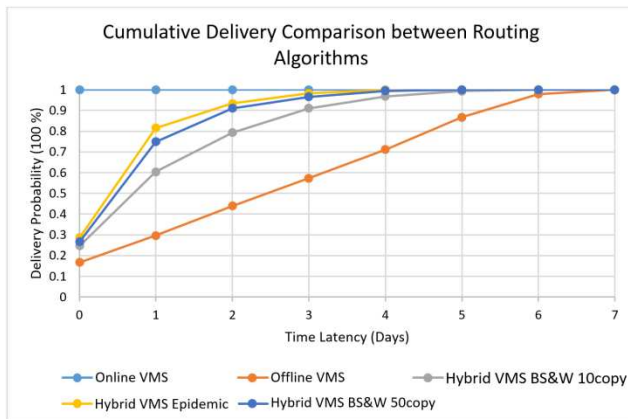
Figure 7. Cumulative delivery performance comparison of routing algorithms

5. Conclusion

Hybrid Vessel Monitoring System (hybrid VMS) is a new alternative scheme of VMS based on Disruption-Tolerant-Networks (DTN) and Internet collaboration. Hybrid VMS speed up offline vessel's data delivery up to twice faster in 98 % of data delivery probability and 1.5 faster in 100 % data delivery probability. Although Hybrid VMS is not as fast as online VMS, Hybrid VMS is more flexible than a pure online VMS scheme. The flexible design is achieved by temporarily switching role as offline vessel when they have financial crisis and using internet again when their revenue is returned. Based on efficiency analysis, the most suitable routing algorithm for Hybrid VMS is Spray and Wait Routing.

References

[1] FAO Technical Guidelines for Responsible Fisheries - Fishing Operations - 1 Suppl. 1 – 1, Vessel Monitoring Systems, Food and Agriculture of the United Nations, Rome, 1998.

[2] *Rancang Bangun Sistem Pemantau Kapal Penangkap Ikan*: Internal report for 2013, Research Center for Informatics, Indonesian Institute of Sciences, Bandung, Indonesia, 2013.

[3] Arfianto, A. Z., & Affandi, A., *Rancang Bangun Layanan Website Interaktif pada Sistem Komunikasi Vessel Messaginng System* (VMeS), Bachelor Thesis, Surabaya Institute of Technology, Surabaya, Indonesia, June. 2010.

[4] Wang, D., Hong, F., Yang, B., Zhang, Y., & Guo, Z., *Analysis on communication capability of vessel-based ocean monitoring delay tolerant networks*, In Wireless Communications and Networking Conference Workshops, IEEE , 2013, pp. 200-204.

[5] Qin, S., Feng, G., Qin, W., Ge, Y., & Pathmasuntharam, J. S., *Performance modeling of data transmission in maritime delay-tolerant-networks*, In Wireless Communications and Networking Conference (WCNC), IEEE, 2013, pp. 1109-1114.

[6] Chuang, Y. J., & Lin, K. C. J., *Cellular traffic offloading through community-based opportunistic dissemination*, In Wireless Communications and Networking Conference (WCNC), IEEE, 2012, pp. 3188-3193.

[7] Keränen, A., Ott, J., & Kärkkäinen, T., *The ONE simulator for DTN protocol evaluation*, In Proceedings of the 2nd international conference on simulation tools and techniques, 2009, p. 55.

[8] Vahdat, A., Becker, D, *Epidemic Routing for Partially-Connected Ad Hoc Networks*, Technical Report, Dept. of Computer Science, Duke University, 2000.

[9] Spyropoulos, et.al., *Spray and Wait: An efficient routing scheme for intermittently Connected Mobile network*, In Proc. ACM SIGCOMM workshop on DTN, Philadelphia, PA, USA, 2005.

[10] Lindgren, A., Doria, A., Scheln, O., *Probabilistic Routing in Intermittently Connected Networks*, In Proc. SIGMOBILE Mobile Computing and Communication Review, 2004.

[11] Capture Fisheries Statistics of Indonesia 2011, Directorate General of Capture Fisheries, Ministry of Marine Affairs and Fisheries, Jakarta, Indonesia, 2012.

[12] Roy, R. R., *Handbook of mobile ad hoc networks for mobility models*, Springer Science & Business Media. New York, 2011.

[13] Basuki, A. I., & Wuryandari, A. I., *Delay-tolerant-networks design and prospect on fishery communication networks*, In System Engineering and Technology (ICSET), IEEE 4th International Conference, 2014, Vol. 4, pp. 1-6.