

Satellite beam handoff detection algorithm based on RCST mobility information

Ji Nyong Jang, Min Woo Lee, Eun Kyung Kim, Ki Keun Kim and Jae Sung Lim

Abstract—Since DVB-RCS has been successively implemented, the mobile communication on the multi-beam satellite communication is attractive attention. And the DVB-RCS standard sets up to support mobility of a RCST. In the case of the spot-beam satellite system, the received signal strength does not differ largely between the center and the boundary of the beam. Thus, the RSS based handoff detection algorithm is not benefit to the satellite system as a terrestrial system. Therefore we propose an Adaptive handoff detection algorithm based on RCST mobility information. Our handoff detection algorithm not only can be used as centralized handoff detection algorithm but also removes uncertainties of handoff due to the variation of RSS. Performances were compared with RSS based handoff algorithm. Simulation results show that the proposed handoff detection algorithm not only achieved better handoff and link degradation rate, but also achieved better forward link spectral efficiency.

Keywords—DVB-RCS, satellite multi-beam handoff, mobility information, handover

I. INTRODUCTION

SATELLITE communication system is essential to the maritime and aerospace environment where is not established infrastructure. And satellite communication is a broadband communication system to support maritime terminals such as merchant ships, battle ships, maritime platforms and fishing boats. But fixed DVB-RCS couldnt be implemented to the maritime environment. Even if maritime RCSTs are not mobile, RCSTs could not be fixed because of ocean currents. Recently, The DVB-RCS standard sets up to support mobility of a RCST, and proposed a process of beam handoff. Handoff strategy is processed by three phases as follows. First phase: Handoff detection determines the necessity for the mobile RCST to be handed over, and typically determines a list of candidate beam. A position based handoff detection approach is suggested in the standard as a baseline. Handoff detection process can be distributed by RCSTs or centralized by a NCC (network control center). Second phase: handoff decision phase is selecting a target beam to be handed over by consideration of candidate beam resource, and issuing handoff command. Third phase: handoff execution is handing off a RCST from a set of resources in the current beam to another set of resources allocated in the target beam [1]. Numerous researches have been studied to support handoff decision phase [3]-[4]. But there is no specific position based algorithm to

support handoff detection phase. Studies in [5]-[6], RSS is a main factor to support handoff detection phase. However, RSS does not differ largely between the center and the boundary of a beam, whereas a terrestrial communication system has noticeable difference of RSS. RSS of satellite beam can be more changed by rain attenuation or jamming signal compare to the clear sky. Especially, in the case of the maritime or aerial scenario, satellite communication is essential for the deteriorating weather or battle situation. Since RSS of adjacent beam is not severely different and the hysteresis margin is small in order to handoff a RCST in the high beam boundary, if there are temporary variation of RSSs near the cross point of beams boundary, RSS based handoff detection algorithm will cause to repeat back and forth handoffs. Therefore we propose adaptive handoff detection algorithm based on RCST position and velocity to prevent back and forth handoffs, even if there are temporary high RSSs variation. The remainder of this paper is organized as follows. Section 2 describes the background of the DVB-RCS and related works about RSS based handoff detection and handoff decision/execution algorithm. Section 3 describes characteristic of spot-beam satellite signal. Proposed adaptive handoff detection algorithm is presented in Section 4. Simulation results are presented in Section 5. Finally we conclude this paper in Section 6.

II. BACKGROUND AND RELATED WORK

Position based spot beam handoff is suited for the DVB-RCS system because position information is already a requisite in mobile DVB-RCS. The RCST uses SAC (satellite access control) field in one of SYNC slot for the purpose of requesting capacity, sending CSI (channel state information) and mobility control messages to the NCC. And RCSTs periodically send SYNC burst every superframe [2].

RCSTs monitor its own position or RSS (received signal strength) to detect the necessity of handoff. When handoff detected, RCST sends a handoff request message to the NCC. This approach is distributed handoff detection approach. Otherwise, centralized handoff detection approach is what all processing is done in the NCC. And then, NCC makes the handoff decision.

After handoff decision processes, Handoff execution Initialize. NCC sends the handoff command to the RCST with information about to be used in the target beam. Overall DVB-RCS beam handoff process is shown as Fig.1.

A. RSS based handoff detection algorithm

Traditional handoff detection algorithms are based on the RSS measurement. Hysteresis margin and RSS threshold are

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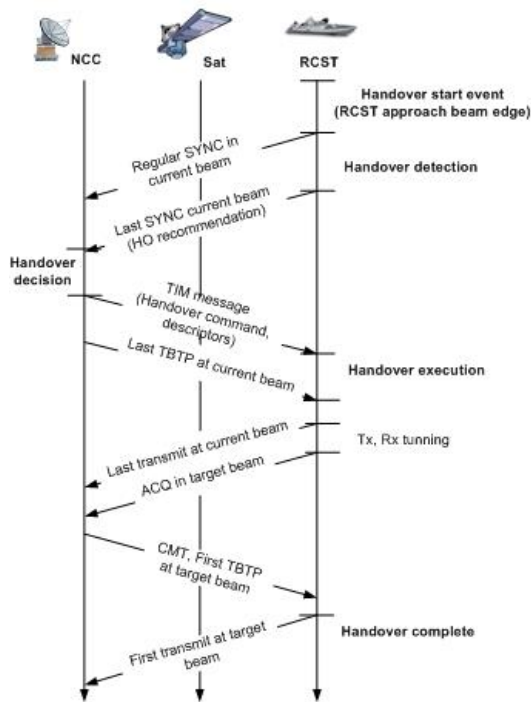


Fig. 1 DVB-RCS beam handoff process

target beam resources are enough to support to handoff, handoff is immediately decided. However, if not, handoff request may be queued. Handoff decisions that rely on exclusively on position information without any prioritization strategy may lead to high handoff failure rates. So they classified of a RCST such as aircraft, high-speed train by the velocity. RCSTs estimate of residual time of current spot beam by using of a target beam approach velocity (TBAV) and a distance of beam edge. handoff request is prioritized by the NCC according to the residence time value. This handoff decision algorithm shows that lower handoff failure probability and higher new connection blocking probability. The authors in [7] proposed handoff execution algorithm. They pay attention to the process of after handoff decision. After handoff decision, NCC sends a TIM (terminal information table) message to the RCST. If TIM message is lost, handoff execution will be fail. So they proposed the NCC with memory for the lower the handoff failure probability. Briefly, the prior researches only pay attention to the after position based handoff detection phase. On the other hand, we concentrate on the phase of handoff detection. We first analyzed characteristics of the spot beam satellite signal. And then compared the RSS based handoff detection algorithm with handoff detection algorithm based on RCST mobility information.

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used to prevent the ping-pong effect. The authors in [5] proposed the adaptive handoff algorithm for multi-beam GEO satellite. They proposed a sampling algorithm and adaptive handoff algorithm. The RSS sampling algorithm is what the number of RSS sampling is determined by velocity of a RCST. Adaptive handoff algorithm is what RSS hysteresis margin is determined adaptively by sampling measurement and velocity of a RCST. This algorithm shows that the hysteresis margin decreases when RSS measurements go down and velocity of a RCST is faster. However, in the case of the maritime and aerial scenario, the RSS of adjacent beam is not severely different from current beam. And not change largely in the clear sky. Therefore, the hysteresis margin should be small to handover trigger occurs in the overlap region. But, this causes an uncertain handover trigger if the temporary degradation of channel quality occurs.

The authors in [6] proposed the adaptive handoff algorithm based on distance information. RSS hysteresis margin is determined adaptively by the distance between the MS (mobile station) and the serving BS (base station). This algorithm shows that the position of MS is closer to the cell radius, the hysteresis margin decrease so as to easily handover trigger.

If the distance between the MS and the serving BS is equal to the cell radius, hysteresis margin become zero. However, because maritime and aerial environment is LOS (line of sight), if we use this kind of handoff detection algorithm, many handoffs will be provoked near the intersection of the beams boundary

B. Handoff decision / execution algorithm

The authors in [3][4] proposed DVB-RCS handoff scheme for supporting handoff decision. After handoff detection, if

III. CHARACTERISTICS OF THE SPOT-BEAM SATELLITE SIGNAL

A. Characteristics of Terrestrial signal

In General, handoff detection is based on RSS in the terrestrial communication system. In case of the terrestrial system, RSS is affected by small fading and large fading. Small fading is caused by delay spread and Doppler Effect. Large fading is caused by shadow fading. Thus, RSS of terrestrial is can be express as Eq. 1. [8].

$$P_R = P_T \cdot G_R \cdot L^{-\alpha} \cdot 10^{\frac{\theta}{10}} \quad (1)$$

where P_R , P_T , G_R , L , α and θ represent RSS, transmitter power, antenna gain, distance between transmitter and receiver, path loss exponent, shadow fading component. However rapid fluctuations due to small fading can be ignored by averaged over sampling. So the main reasons of variation of RSS are shadowing and path loss. Thus RSS is highly dependent on location condition of a terminal. Therefore, the RSS of terrestrial system is change largely. As a result, if a terminal handoff to other cell, RSS hysteresis margin must be large enough to prevent ping pong effect.

B. Characteristics of multi-beam satellite signal

RSS of Satellite is can be express as Eq. 2. [9].

$$P_R = \frac{P_T \cdot G_T \cdot G_R}{L_P \cdot L_{TX} \cdot L_A} \quad (2)$$

where P_R , P_T , G_T , G_R , L_P , L_{TX} , L_A represent RSS, transmitter power, transmitter antenna gain, receiver antenna gain, path loss, transmitter antenna gain loss of position offset, atmospheric attenuation. Due to the satellite system in the

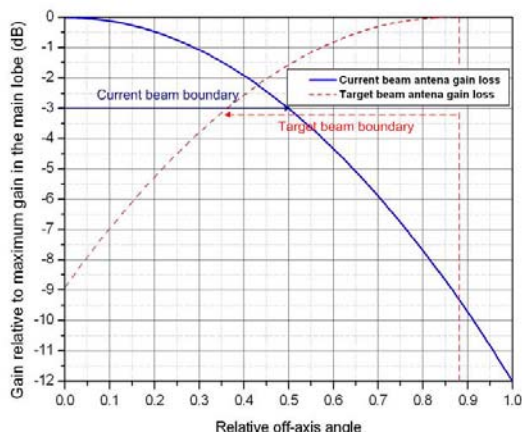


Fig. 2 Antenna gain loss of position offset

maritime and aerial environment are LOS and there is very little difference of the distance between GEO satellite and center and edge of the beam. There is very little difference of path loss, and the RSS of satellite system is not change largely. Main reason of RSS variation is antenna gain loss of position offset and atmospheric attenuation. In general, satellite directional antenna gain loss of position offset is 3dB at the beam boundary. And RSS may be more attenuated by interference of adjacent beam, near the beam boundary. Therefore, when design a link budget of satellite system, Antenna gain loss of position offset must be considered. Antenna gain loss of position offset can be express as Eq. 3. [1].

$$L_{TX} = 12 \cdot \left(\frac{\theta_T}{\theta_{3dB}} \right)^2 \quad (3)$$

Where L_{TX} , θ_T , θ_{3dB} represent transmitter antenna gain loss of position offset, angle of satellite to RCST, beam width. Antenna gain loss of position offset according to relative off axis angle is shown as Fig.2. at the beamwidth as 1

And second variation factor of RSS is Atmospheric attenuation. This atmospheric attenuation is highly time dependent. Generally atmospheric attenuation is very small (e.g. 0.2dB). But when it rain fall, RSS of satellite is severely influenced by rain attenuation at ku, ka band (e.g. 5dB). Thus variation of RSS in rain sky is larger than that of clear sky. So satellite system is designed to overcome rain attenuation. Thus, point of view about RSS, spot beam is divided into high beam area and low beam area as Fig.3. In the clear sky, If CCM (constant coding and modulation) is applied in satellite system, satellite communication can be guaranteed on low beam area caused by rain attenuation margin.

However in the rain sky, satellite communication is only guaranteed on high beam area. So if handoff detection is delayed out of high beam boundary, satellite link will be degraded. Recently DVB-S2 applies of ACM (adaptive coding and modulation) to increase resource utilization. So even if handoff detection delayed to the low beam area, QoS

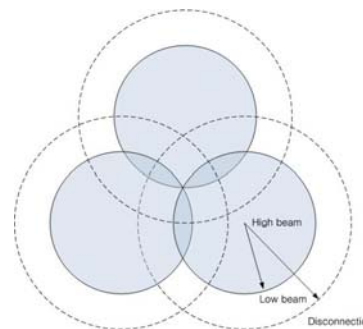


Fig. 3. spotbeam arrangement

of satellite communication could be guaranteed. But overall spectral efficiency will be degraded. thus, it is desirable to handoff detected in high beam overlap region, as soon as RCST cross the point of same RSS. If satellite handoff strategy applies of RSS based handoff detection algorithm, hysteresis margin must be not large but also too small for the purpose of handoff detected in the high beam boundary and prevent a ping pong effect. However, RSS of satellite in the overlap region is almost no difference between current beam and adjacent beam. In order to handoff detected in high beam overlap region, hysteresis margin shouldn't be bigger as terrestrial system. But this cause uncertain handover trigger if there is temporary degradation of channel quality. Thus, we proposed a distance margin concept and adaptive handoff detection algorithm based on RCST mobility information that reduced handoff rate and link degradation rate.

IV. ADAPTIVE HANDOFF DETECTION ALGORITHM BASED ON RCST MOBILITY INFORMATION

A. Handoff detection algorithm

In DVB-RCS standard, mobile RCST can measure its position by navigational system (e.g. GPS/Galileo) for the purpose of time synchronization. And a RCST knows about centers of current beam and adjacent beams. Thus, RCST can know the distance between the center of current beam and the candidate beams. So we can simply consider of absolute position based handoff detection algorithm. But in the case of the frequently changing of a RCST mobility at the same distance position between the current beam and the target beam, repeat back and forth handoffs will be occurred because of RCST mobility pattern. If we consider the beam boundary as a position threshold, link degradation rate will be increased or overall spectral efficiency will be reduced. We can consider of relative position based handoff detection algorithm. We can use a distance margin as a RSS hysteresis margin. This distance margin can reduce the back and forth handoffs. But if we set static distance margin, many handoff detection will be occurred out of the high beam boundary, near the intersection of beam edge. This may cause to increase of link degradation or reduce the overall spectral efficiency. So we propose an adaptive distance margin based on RCST mobility information. If target beam approach velocity (TBAV) of a RCST is fast, it is desirable to handoff detected as fast as possible. Since this kind of a RCST has high probability

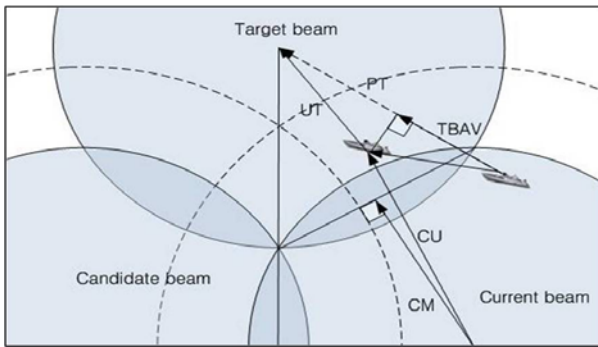


Fig. 4 proposed handoff detection situation

of handoff. Also it has only short time until arrive to the low beam area. Thus, the TBAV is faster, the distance margin must be smaller to be easily handoff detected. On the other hands, TBAV is slower, the distance margin must be larger to reduce the handoff rate. Besides, to reduce the back and forth handoff caused by frequent course change of the RCST, distance margin should be adjusted by TBAV of the RCST. If the distance margin only be adjusted by the TBAV of the RCST and the TBAV is very slow, distance margin can be too large to restrain handoff detection. This cause a increasing of link degradation and decreasing of the resource utilization at the edge of the beam. Thus, distance margin should be adjusted by relative position of a RCST in the overlap region. Therefore we considered the TBAV and the relative position of a RCST, in order to determine the distance margin. We assumed that the position measurement is detected by a RCST, and this position information is reported to the NCC per every minute [superframe]. Also we assumed that the beam width as a 0.5, considering of Antenna technology development. The overall proposed handoff detection situation is described as Fig.4.

The target beam approach velocity of a RCST is calculated as Eq. 4.

$$TBAV_m = \max (|PT| - |Proj_{PT}^{(UT)}|, 0) \quad (4)$$

Where TBAV_m, UT and PT represent target beam approach velocity of RCST per minute, the vector that current position of the RCST to the center of target beam and the vector that preposition of the RCST to the center of target beam . Adaptive distance margin is calculated as Eq. 5

$$d_{AM} = \frac{8}{\sqrt{TBAV_m}} \left(\frac{|CU|}{|CM|} \right)^5 \quad (5)$$

By Eq. 5 distance margin is adaptively adjusted by position of a RCST and TBAV. Where d_{AM}, and CU, CM represent adaptive distance margin, the vector that center of the current beam to current position of a RCST, and the vector that the center of current beam to the middle point between the current beam and the target beam center. The coefficient 8 determines range of adaptive distance margin. Maritime RCST can maneuver back and forth by ocean current (e.g. 4km/h) with no intention of maneuvering. Thus, the coefficient is chosen to be 8km in order to reduce unnecessary handoff cause by the RCST mobility pattern. And the exponent determines

the reduction rate of adaptive distance margin according to the distance from the current beam center. The larger the exponent, the reduction rate more increase. This means that the distance margin is more affected by position information. In this paper we set a default exponent as a 5 to the handoff detected in high beam area, even if TBAV is small as 4km/h.

Adaptive handoff detection algorithm is analyzed as Fig.5. If the current beam distance of a RCST is larger than sum of the target beam distance and distance margin, handoff is detected. As the relative position of a RCST is closer to the beam center and the TBAV is smaller, the distance margin becomes larger. as a result, handoff detection is restraint. If a RCST mobility patterns are right side of handover trigger point, handoff is detected. And a RCST recommend to the NCC for handoff or NCC could judge the handoff detection by a RCST mobility information. On the other hand, handoff detection is restraint if a RCST mobility patterns are left side of handover trigger point. So this handoff detection algorithm could be apply to the centralize handoff detection algorithm as well as distributed algorithm. And if the NCC has this handover trigger data base, this algorithm could be applied to the handoff decision algorithm. After handoff is detected, NCC considers of target beam resource. If the target beam resource is not enough to support Qos of a RCST, handoff request is blocked and queued. If target beam resource is not available until handoff request queue threshold, handoff request is dropped. If multiple RCST request handoff, we must consider of handoff priority. On the graph, NCC could prioritize of handoff by Euclid distance between handover trigger point and RCST mobility pattern. If multiple RCST request handoff, The RCST that mobility pattern is farthest from the handover trigger point implement the handoff. Our handoff detection algorithm Reflect the priority to the fast RCST by considering of TBAV of a RCST at the process of handoff detecion.

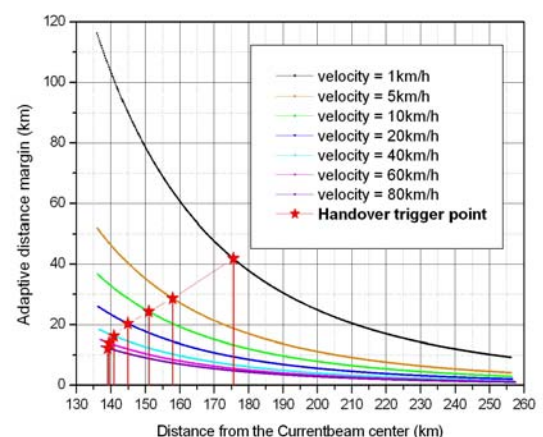


Fig. 5 Adaptive distance margin with RCST mobility informaiton

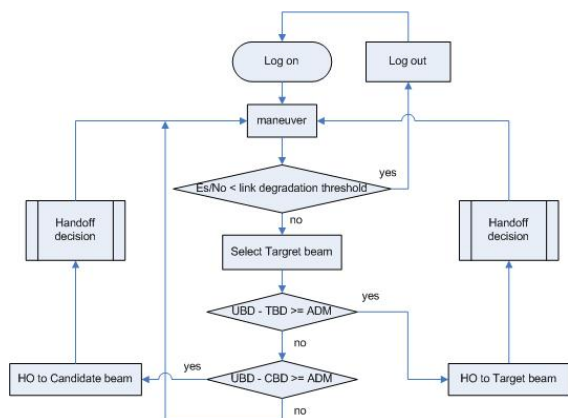


Fig. 6 Overall handoff detection procedure

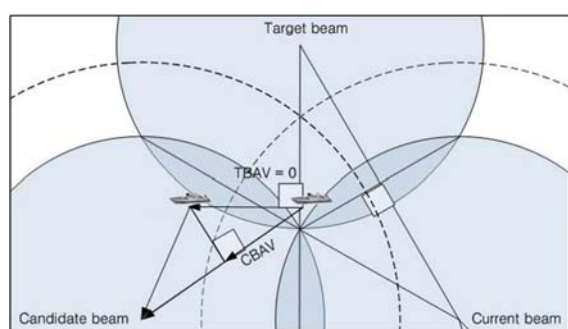


Fig. 7 Candidate beam handoff situation

B. Overall handoff detection procedure

Fig.6. shows that the overall handoff detection procedure. Log on RCST measure the channel state. If channel state is lower than link degradation threshold, RCST may be log out, or RCST rank the adjacent beams in order of closest distance from the beam center. And then select the first ranked adjacent beam as a target beam, and next ranked beam as a candidate beam. After that, RCSTs or NCC perform the Adaptive handoff detection algorithm based on RCST mobility information. If current beam distance (UBD) is greater than sum of the target beam distance (TBD) and adaptive distance margin (ADM). The RCST is handed off to the target beam.

However, if the RCST is not in the current high beam boundary but in the target high beam boundary, and the RCST is going away from the target beam center as a Fig.7., handoff detection is delayed until the target beam changing. This cause increasing link degradation rate or lower the resource utilization. Thus, it is desirable that consider a candidate beam handoff. If the UBD is greater than sum of candidate beam distance (CBD) and ADM, The RCST is handed off to the candidate beam.

V. SIMULATION RESULTS

In this section, performances of the proposed handoff detection algorithm have been evaluated. Simulation parameters are shown as Table. I.

We assumed that RCSTs are uniformly distributed on 3 beams. And beam width is 0.5. Total number of employed

RCSTs is 70. RCSTs and Rain cloud move as simulation mobility pattern. If a distance between a RCST and the center of the rain cloud is closer than 20km, RCST experience of average 5dB rain attenuation. Otherwise, RCST experience of average 2dB rain attenuation. We also follow the RSS sampling algorithm in [5]. Forward link frequency, bandwidth, symbol rate and Fecframe length are assumed to be as 30GHz, 27MHz, 25Mpsps and 64800bit. Transmitter power of Satellite, transmitter antenna gain and RCST receiver antenna gain are assumed to be as 10dBm, 55dB, 40dB. The threshold of link degradation is assumed to be -126.8085dB, below which the link is dropped. And the RCST is logged out. We concentrate on the variation of the atmospheric attenuation. In clear sky, RCSTs generally experience of atmospheric attenuation as 0.2dB. In rain sky, RCSTs generally experience of rain attenuation as 5dB at the Ku band. We assumed that the variation of rain attenuation is more severe than atmospheric attenuation. Thus, we evaluated handoff performances according to the variation of rain attenuation. The average handoff rate, average link degradation rate are used as criteria for the performance evaluation. handoff performances are compared with RSS based handoff algorithm such as Static Hysteresis Margin (SHM), Adaptive Hysteresis Margin (AHM) and Adaptive handoff algorithm based on distance information (AHMBD). And take into account employing of ACM, Average forward link throughput and Average forward link delay are evaluated.

Fig.8.9. are simulated based on the variation of rain attenuation as a 0.1. Fig.8. shows that average handoff rate according to RSS hysteresis margin. The number of handoff decrease with increasing hysteresis margin. Proposed adaptive handoff detection algorithm is not affected by RSS hysteresis margin but only affected by the RCST mobility information. So the handoff rate is static according to the RSS hysteresis margin. Handoff rate of ADM is similar to the hysteresis margin as 0.8dB on the RSS based handoff detection algorithm. In the adaptive handoff algorithm based on distance information

TABLE I
SIMULATION PARAMETERS

parameters	value
Simulation Time	5hour
Number of beams	3
Beam width	0.5
Number of RCSTs	70
RCST velocity	6 - 80kmph
RCST Course change rate	5 - 15 / 15min
Rain attenuation	2, 5dB
Forward link frequency	30Ghz
Forward link bandwidth	27Mhz
Forward link symbol rate	25Mpsps
Forward link Fecframe length	64800bit
Transmit power of satellite	10dBm
Satellite transmitter antenna gain	55dB
RCST receiver antenna gain	40dB
Threshold of Link degradation	-126.8085dB

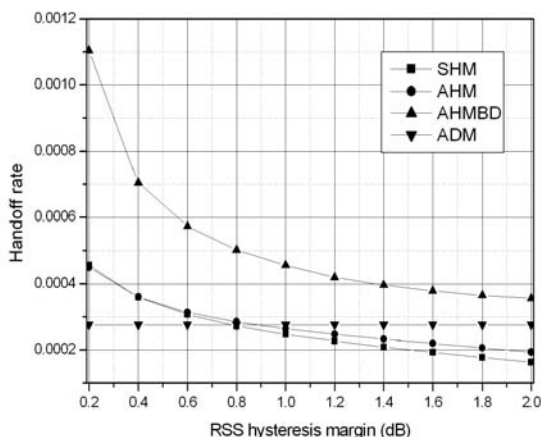


Fig. 8 Handoff rate according to the hysteresis margin

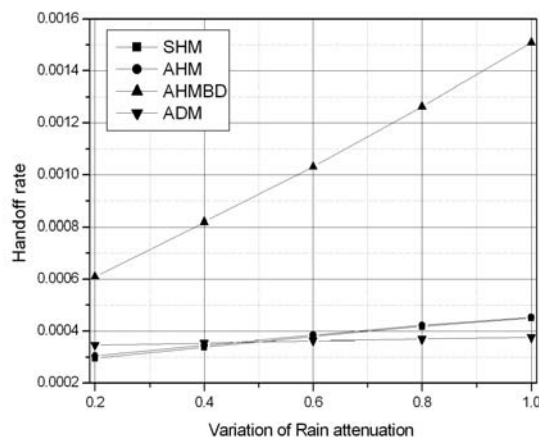


Fig. 10 Handoff rate with variation of rain attenuation

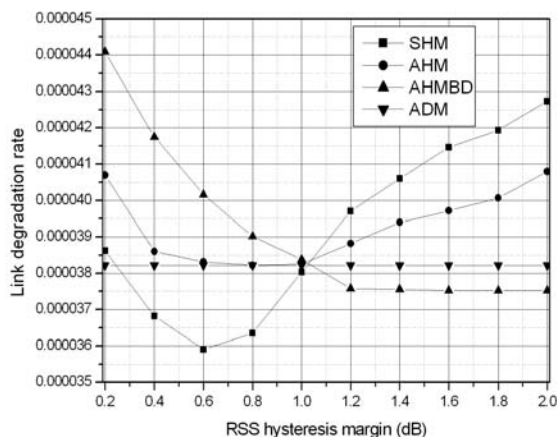


Fig. 9 Link degradation rate according to the hysteresis margin

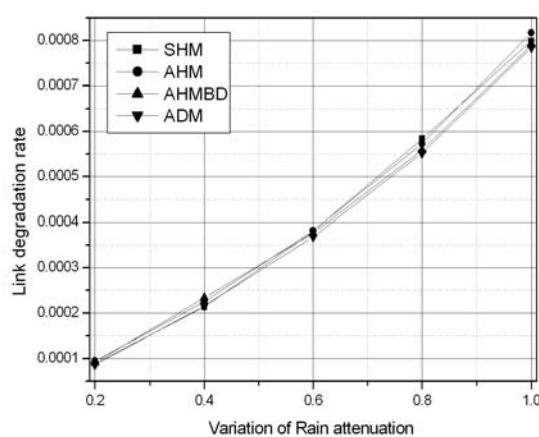


Fig. 11 Link degradation rate with variation of rain attenuation

(AHMBD), handoff rate is decreased with increasing hysteresis margin. However, handoff rate is seriously greater than other handoff detection algorithms.

Fig.9. shows that average link degradation rate according to the RSS hysteresis margin. At the Static handoff algorithm (SHM) and adaptive handoff algorithm (AHM), link degradation rate is lowest around hysteresis margin at 0.8dB. Upper and lower of hysteresis margin at 0.8dB, link degradation rate is increasing. If we set of RSS hysteresis margin as lower of 0.8dB, uncertain handoff occur by RSS variation. This is a causative of increasing link degradation rate. And if we set of RSS hysteresis margin as upper of 0.8dB, hand off detection is delayed out of high beam boundary. This is a causative of increasing link degradation rate. At the adaptive handoff algorithm based on distance information (AHMBD), link degradation rate is decreased with increasing hysteresis margin up to 1.2dB. Link degradation rate does not decrease any more upper of hysteresis margin at 1.2dB. By this result, we can know the handoff rate and link degradation rate are

relation of contradiction. Thus we set a RSS hysteresis margin as 0.8dB to keep a lowest link degradation rate.

Fig.10. shows that average handoff rate according to the variation of rain attenuation. At the RSS based handoff detection algorithm, handoff rate increases with increasing the variation of rain attenuation. This means that uncertain handoff occurs. However, at the ADM, handoff rate is almost same with increasing the variation of rain attenuation.

Fig.11. shows that average link degradation rate according to the variation of rain attenuation. Link degradation rate increases with increasing the variation of rain attenuation. The variation of rain attenuation is more increase; satellite communication guarantee area is more decrease. This means that link degradation occur in the high beam area at the severe variation of rain attenuation. If we analyze the other point of view, ADM shows that the lowest link degradation rate. And the difference of link degradation rate is greater with increasing of variation of rain attenuation. This means that ADM shows the greater handoff performance at the temporary

VI. CONCLUSION

In this paper, we introduced DVB-RCS spot beam handoff process. We analyzed the RSS characteristic of multi-beam satellite. And proposed adaptive handoff detection algorithm based on RCST mobility information with an adaptive distance margin concept. This handoff detection algorithm can be applied to not only distributed handoff approach but also centralized handoff approach. NCC can prioritize of handoff if proposed algorithm is applied to the centralized handoff approach.

Simulation results show that the proposed adaptive handoff detection algorithm achieved similar performance respect to the handoff rate, and link degradation rate on the condition of low RSS variation (i.e. clear sky), and achieved better performance on the condition of severe RSS variation (i.e. rain sky). Considering the ACM is applied to the forward link, Simulation results show that the proposed adaptive handoff detection algorithm achieved the better resource utilization. In the near future, we will study handoff strategy to improve return link resource utilization and handoff decision algorithm for suitable to the maritime military situation.

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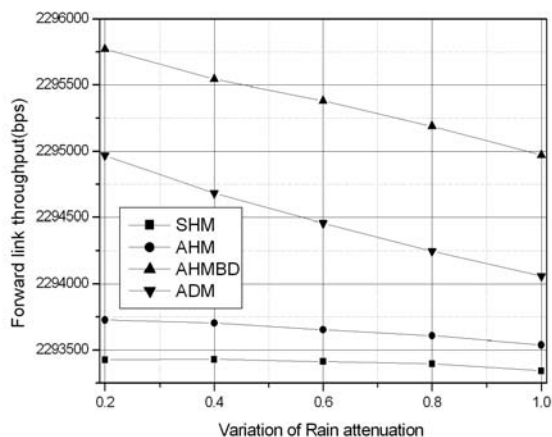


Fig. 12 Fwd link throughput with variation of rain attenuation

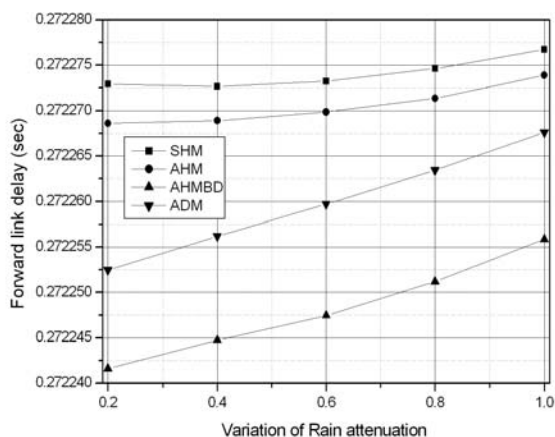


Fig. 13 Fwd link delay with variation of rain attenuation

high RSS variation situation.

Fig.12. shows that Forward link throughput according to the variation of rain attenuation. Forward link throughput decreases with increasing variation of rain attenuation. And ADM shows the greater forward link throughput than SHM and AHM. This is the reason that the proposed handoff detection algorithm has greater variance of handoff detection point. If the TBAV of a RCST is fast, handoff is detected as fast as possible. This kind of a RCST has better channel state than SHM and AHM. Applying ACM, forward link resource utilization increases. On the other hand, as the variation of rain attenuation increases, forward link throughput decreasing rate is more than SHM and AHM. This is the reason that forward link throughput of ADM is more affected by variation of RSS than SHM and AHM, since ADM has greater variance of handoff detection point than SHM and AHM.

Fig.13. shows that Forward link delay according to the variation of rain attenuation. Forward link delay increases with increasing the variation of rain attenuation.