Load Balancing Scheme Based on Real Time Traffic in Wibro

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Abstract. The WiBro operates at the 2.3GHz broadband and the communication infrastructure is a cellular system. The WiBro is based on IEEE 802.16e standard and it is designed to maintain connectivity on mobile environment at a speed of up to 60 km/h. ACR(Access Control Router) manages several RAS(Radio Access Station). When mobile node moves to another domain from the present domain, which is managed by different ACR, MN sends Binding Update to HA (Home Agent) or CN (Correspondent Node). However ACR may be a single point of performance bottleneck because the ACR should not only handle signaling traffics but also process data tunneling traffic for all MNs registered in its domain. In this paper, we propose ACR load balancing method by priority queue. Quantitative results of the performance analysis show that our proposal has superior performance.

Keywords: Wibro, ACR, real time data, non real time data, queue.

1 Introduction

In February 2002, Korean government allocated 100 MHz bandwidth of 2.3GHz spectrum band for wibro(Wireless Broadband)system. WiBro allows subscribers to use high-speed Internet more economically and more widely, even when moving at the speed of about 60km per hour [1]. As illustrated in figure 1, the wibro system consists of PSS(Portable Subscriber Station), RAS(Radio Access Station), ACR (Access Control Router) and IP based backbone networks[2,3].

Figure 1(a) and (b) show two cases of WiBro structure. Figure 1(a) has two subnets and each ACR manages several RAS within a subnet.

In this paper, we only consider the situation when a mobile node moves to another subnet, which is managed by different ACR.

All mobile nodes included in an ACR are to have mobility. Therefore, if MN increases to control by ACR, ACR grow BU(Binding Update). As a result, ACR cannot respond quickly to real time data rather than non real time data.

The rest of the paper is organized as follows. Section 2 presents the previous works about mobile multimedia process in WiBro. Section 3 proposes our method. Section 4

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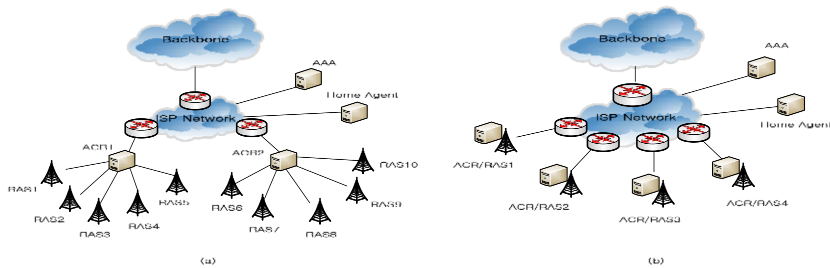


Fig. 1. A structure of WiBro

evaluates the performance and analyzes numerical results. Finally, we conclude this paper in section 6.

2 Related Work

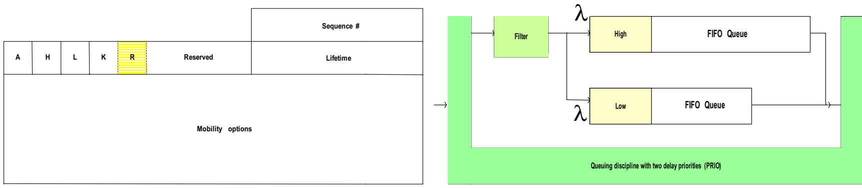
Shim, Kim and Ra [4] proposed a handover scheme for an efficient and reliable multicast routing over WiBro service. In order to dynamically manage each multicast flow and minimize the frequency of the multicast group join while guaranteeing the optimal path, they adopted FA based multicast routing scheme that is based on hierarchical architecture among ACR and RASs.

This paper has attempted to justify that sleep mode can be effective even in a mobile environment by adopting the optimized initiation process [5] and Wu and Kim proposed an efficient direction and speeds based handover connection control schemes for increasing the utilization of channels and reduce a probability of new connection blocking rate [6].

They proposed an efficient IPv6 based fast handover scheme for seamless interdomain mobility support over WiBro networks considering cross-layer approach [7]. The FMIPv6 protocol has problem to be used with WiBro system, owing to difficulty in utilizing the layer 2 handover information. So, Shim, Kim and Lee proposed mechanism that can provide effective fast handover in IPv6 based WiBro system [8] and W. Lee et al proposed an adaptive vertical handoff decision scheme called Ubi-Comm which is an improved handover decision algorithm that avoids the ping-pong effect [9]. In [10], they proposed algorithm utilizes the user based scheduling to relieve the MAP(Mobility Anchor Point) overhead problem and to modify the normal proportional fair scheduling algorithm to guarantee user based QoS.

3 Proposed Method

As mentioned above, ACR may be a single point performance bottleneck because the ACR should not only handle signaling traffic but also process data tunneling traffic for all MNs registered to the ACR domain. There are many works performed on multimedia data process, but not on BU (Binding Update) process in ACR. As such, we propose new method to operate BU in ACR's waiting queue in order to update new location of MN rapidly.



(a) New binding update message

(b) Binding update processing with priority queues in ACR

Fig. 2. The process of proposed method

We show the priority process of ACR in (a) of Fig 2. For an instance, if ACR has many MN of mobility, ACR increases the overall BU process. Compared to the existing method, which has only one queue, waiting time is increased. Besides, existing method employs FIFO. However, if our proposed method is applied, there would be two queues and the general performance is improved when the waiting time decreases. Fig. 3 shows proposed system model.

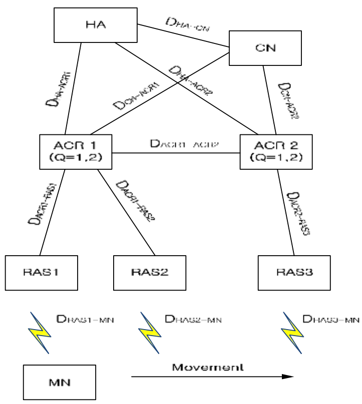


Fig. 3. The picture is proposed method

4 Numerical Analysis

4.1 Mobility Model

We assumed that there is hexagonal cellular network architecture, as shown in Fig. 4. Each ACR domain consists of the different number of range rings, D. Rings of cells surround each cell as illustrated in Fig. 4 [11]. Each ring d (d>=0) is composed of 6d cells. The innermost cell "0" is called the center cell. The number of cells N (D) is calculated using the following equation:

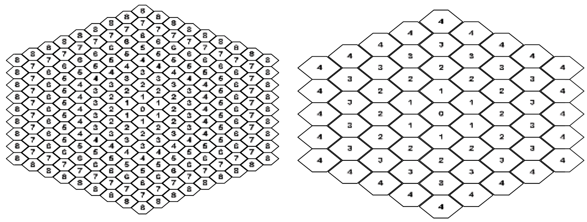


Fig. 4. Hexagonal Cellular Network Architecture (D=8, D=4)

$$N(D) = 1 + 6 \cdot \sum_{d=1}^{D} d = 1 + 3 \cdot D \cdot (D+1) \tag{1}$$

Hexagonal cellular network architecture (D=8) of Fig. 4 shows the proposed hexagonal cellular network architecture of traffic characteristics.

The two-dimensional model used in Markov chain model with respect to the user mobility model is considered [12]. In this model, the next position of an MN is equal to the previous position in addition to a random variable whose value is drawn independently from an arbitrary distribution. Besides, an MN moves to another cell area with a probability of 1-q and it remains in the current cell with probability, q. Given an MN located in a cell of ring d (d>0), the probability that a movement will cause an increase (p+(d)) or decrease(p-(d)) in distance from the center cell is given by

$$P^{+}(d) = \frac{2d+1}{6d} \quad and \quad P^{-}(d) = \frac{2d-1}{6d} \tag{2}$$

The state k of a Markov chain is defined as the distance between the current cell of the MN and the center cell. This state is equivalent to the index of a ring in which the MN is located. Therefore, the MN is said to be in state k if it is currently residing in ring d. The transition probabilities $\alpha_{d,d+1}$ and $\beta_{d,d-1}$ represent the probabilities of the distance of the MN from the center cell increasing or decreasing, respectively. They are given as follow, where q is the probability that an MN stays in the current cell:

$$\alpha_{d,d+1} = \begin{cases} (1-q) & if \quad d = 0 \\ (1-q)\,p^{+}(d) & if \quad 1 \le d \le D \end{cases} \tag{3}$$

$$\beta_{d,d-1} = \text{(1-q) p}^{-}\text{(d)} \qquad if \quad 1 \le d \le D \tag{4}$$

We denote $p_{d,D}$ as the steady-state probability of state d within a ACR domain consisting of D range rings. As stated in Equation (3) and Equation (4), $P_{d,D}$ can be expressed in the form of the steady state probability $P_{0,D}$ as shown below:

$$P_{d,D} = P_{0,d} \prod_{i=0}^{d-1} \frac{\alpha_{i,i+1}}{\beta_{i+1,i}} \qquad \text{for } 1 \le d \le D \tag{5}$$

With the requirement $\sum_{d=0}^{D} P_{d,D} = 1$, $P_{d,D}$ can be expressed by

$$P_{0,D} = \frac{1}{1 + \sum_{d=1}^{D} \prod_{i=0}^{d-1} \frac{\alpha_{i,i+1}}{\beta_{i+1,i}}} \tag{6}$$

where $\alpha_{d,d+1}$ and $\beta_{d,d-1}$ are obtained from Equation(3) and Equation(4)

4.2 Cost Functions

The total cost, consisting of location update cost and paging cost, should be considered when analyzing the performance of wireless/mobile networks. The total cost is divided into location update cost and packet delivery cost. In our proposed scheme, we divide total cost into new location update and packet delivery cost. $C_{location}$, $C_{new\text{-}location}$, and C_{packet} denote the location update cost, new location update and the packet delivery cost, respectively. As such, the total cost of MIPv6 (C_{total}) and the proposed scheme ($C_{new\text{-}total}$) can be obtained as follows:

$$C_{total} = C_{location} + C_{packet} \tag{7}$$

$$C_{new-total-high} = C_{NEW-location} + C_{packet-high} \tag{8}$$

$$C_{new-total-low} = C_{NEW-location} + C_{packet-low} \tag{9}$$

4.2.1 Location Update Cost

MN registers its CoA with the CNs and the HA, when a MN moves into a new domain.

$$\begin{aligned} C_g &= 2 \cdot (k \cdot D_{RAS\{1,2,3\}-MN} + \tau \cdot (D_{HA-ACR\{1,2\}} + D_{ACR\{1,2\}-RAS\{1,2,3\}})) \\ &+ 2 \cdot N_{CN} \cdot (k \cdot D_{RAS\{1,2,3\}-MN} + \tau \cdot (D_{HA-ACR\{1,2\}} + D_{CN-ACR\{1,2\}})) \\ &+ (PC_{HA} + W_Q) + N_{CN} \cdot (PC_{CN} + W_Q) + (PC_{ACR} + W_Q) \end{aligned} \tag{10}$$

$$C_l = 2 \cdot (k \cdot D_{RAS\{1,2,3\}-MN} + \tau \cdot (D_{ACR\{1,2\}-RAS\{1,2,3\}}) + PC_{ACR} + W_Q \tag{11}$$

$$\begin{aligned} C_{NEW-g} &= 2 \cdot (k \cdot D_{RAS\{1,2,3\}-MN} + \tau \cdot (D_{HA-ACR\{1,2\}} + D_{ACR\{1,2\}-RAS\{1,2,3\}})) \\ &+ 2 \cdot N_{CN} \cdot (k \cdot D_{RAS\{1,2,3\}-MN} + \tau \cdot (D_{HA-ACR\{1,2\}} + D_{CN-ACR\{1,2\}})) \\ &+ (PC_{HA} + W_Q) + N_{CN} \cdot (PC_{CN} + W_Q) + (PC_{ACR} + W_Q^1) \end{aligned} \tag{12}$$

$$C_{NEW-l} = 2 \cdot (k \cdot D_{RAS\{1,2,3\}-MN} + \tau \cdot (D_{ACR\{1,2\}-RAS\{1,2,3\}}) + PC_{ACR} + W_Q^2 \tag{13}$$

where τ and k indicate the unit transmission costs in a wired and a wireless link, respectively. PC_{HA} and PC_{CN} denotes the processing costs for binding update procedures at the HA and the CN, respectively. Given $D_{HA\text{-}ACR\{1,2,3\}}$, $D_{ACR\{1,2,3\}\text{-}RAS}$, $D_{RAS\text{-}MN}$ and $D_{CN\text{-}ACR\{1,2,3\}}$ as the hop distance between nodes, N_{CN} represents the number of CNs that is communicating with the MN.

In terms of the random walk mobility model, the probability that a MN performs a global binding update is as follows:

$$P_{D,D} \cdot \alpha_{D,D+1} \tag{14}$$

Specifically, if a MN is located in range ring D, the boundary ring of a ACR domain is composed of D range rings, and performs a movement from range ring D to range ring D+1.

$$C_{location} = \frac{P_{D,D} \cdot \alpha_{D,D+1} \cdot C_g + (1 - P_{D,D} \cdot \alpha_{D,D+1}) \cdot C_l}{T} \tag{15}$$

$$C_{NEW-location} = \frac{P_{D,D} \cdot \alpha_{D,D+1} \cdot C_{NEW-g} + (1 - P_{D,D} \cdot \alpha_{D,D+1}) \cdot C_{NEW-l}}{T} \tag{16}$$

where T is the average cell residence time.

4.2.2 Packet Delivery Cost

The packet delivery cost, C_{PACKET}, in WiBro can then be obtained as follows:

$$C_{PACKET} = C_{ACR} + C_{CN-MN} \tag{17}$$

$$C_{PACKET-HIGH} = C_{ACR-HIGH} + C_{CN-MN} \tag{18}$$

$$C_{PACKET-LOW} = C_{ACR-LOW} + C_{CN-MN} \tag{19}$$

C_{ACR} in Equation(17) indicates the processing cost for packet delivery at the ACR, while C_{CN-MN} in figure 3 denotes the packet transmission cost from the CN to the MN.

In WiBro, the processing cost at the ACR is divided into the lookup cost (C_{lookup}), the routing cost ($C_{routing}$) and the waiting time (C_{wait}) in queue. The lookup cost is proportional to the size of the mapping table, whereas the size of the mapping table is proportional to the number of MNs located in the coverage of a domain [13]. On the other hand, the routing cost is proportional to the logarithm of the number of ARs within a particular domain [14]. The waiting time denotes the priority [15]. Therefore, the processing cost at the ACR can be expressed as Equation (25). In Equation (25), λ denotes the session arrival rate while S denotes the average session size in the unit of packet. α and β are the weighting factors, and N_{MN} shows the total number of users located in a domain.

The M/G/1 model assumes (i) Poisson arrivals at rate λ; (ii) a general service distribution; and (iii) a single server. This follows since there is only a single server. Considering expectations of both sides of customer's wait in queue yields

$$W_Q = \text{Average work as seen by an arrival.}$$

However, owing to Poisson arrivals, the average work as seen by an arrival will equal V, the time average work in the system. Hence, for the model M/G/1

$$W_Q = V \tag{20}$$

The proceeding in conjunction with the identity

$$V = \lambda E[S]W_Q + \frac{\lambda E[S^2]}{2} \tag{21}$$

yields the so-called Pollaczek-Khintchine formula:

$$W_Q = \frac{\lambda E[S^2]}{2(1-\lambda E[S])} \tag{22}$$

Priority queuing systems are ones in which customers are classified into types and then given service priority according to their type. Consider the situation where there are two types of customers, who arrive according to independent Poisson processes with respective rates λ_1 and λ_2. Let W_Q^i denote the average wait in queue of a type i customer, i = 1, 2. Our objective is to compute W_Q^i.

The work in the system is exactly the same as the work when there is no priority rule but rather a first-come, first-served (called FIFO) ordering. However, under FIFO the preceding model is just M/G/1 with

$$\lambda = \lambda_1 + \lambda_2 \tag{23}$$

which follows since the combination of two independent Poisson processes is itself a Poisson process whose rate is the sum of the rates of the component processes.

$$W_Q^1 = \frac{\lambda_1 E[S_1^2] + \lambda_2 E[S_2^2]}{2(1-\lambda_1 E[S_1])} \tag{24}$$

$$W_Q^2 = \frac{\lambda_1 E[S_1^2] + \lambda_2 E[S_2^2]}{2(1-\lambda_1 E[S_1] - \lambda_2 E[S_2])(1-\lambda_1 E[S_1])} \tag{25}$$

This paper assumes that the average number of users located in the coverage of an AR is K. Therefore, the total number of users can be obtained using Equation (26).

$$N_{MN} = N_{AR} \times k \tag{26}$$

$$\begin{aligned} C_{ACR} &= \lambda \cdot \overline{S} \cdot (C_{lookup} + C_{routing} + C_{wait}) \\ &= \lambda \cdot \overline{S} \cdot (\alpha N_{MN} + \beta \log(N_{AR}) + W_Q) \end{aligned} \tag{27}$$

$$\begin{aligned} C_{ACR-HIGH} &= \lambda \cdot \overline{S} \cdot (C_{lookup} + C_{routing} + C_{wait}) \\ &= \lambda \cdot \overline{S} \cdot (\alpha N_{MN} + \beta \log(N_{AR}) + W_Q^1) \end{aligned} \tag{28}$$

$$\begin{aligned} C_{ACR-LOW} &= \lambda \cdot \overline{S} \cdot (C_{lookup} + C_{routing} + C_{wait}) \\ &= \lambda \cdot \overline{S} \cdot (\alpha N_{MN} + \beta \log(N_{AR}) + W_Q^2) \end{aligned} \tag{29}$$

Since WiBro supports the route optimization, the transmission cost in WiBro can be obtained using Equation(28). As mentioned before, τ and k denote the unit transmission costs in a wired and a wireless link, respectively.

$$\begin{aligned} & C_{CN-MN} = \tau \cdot \lambda \cdot ((S-1) \cdot (D_{CN-ACR\{1,2\}} \cdot D_{ACR\{1,2\}-RAS\{1,2,3\}}) \\ & + (D_{HA-CN} + D_{CN-ACR\{1,2\}} \cdot D_{ACR\{1,2\}-RAS\{1,2,3\}})) + k \cdot \lambda \cdot S \end{aligned} \tag{30}$$

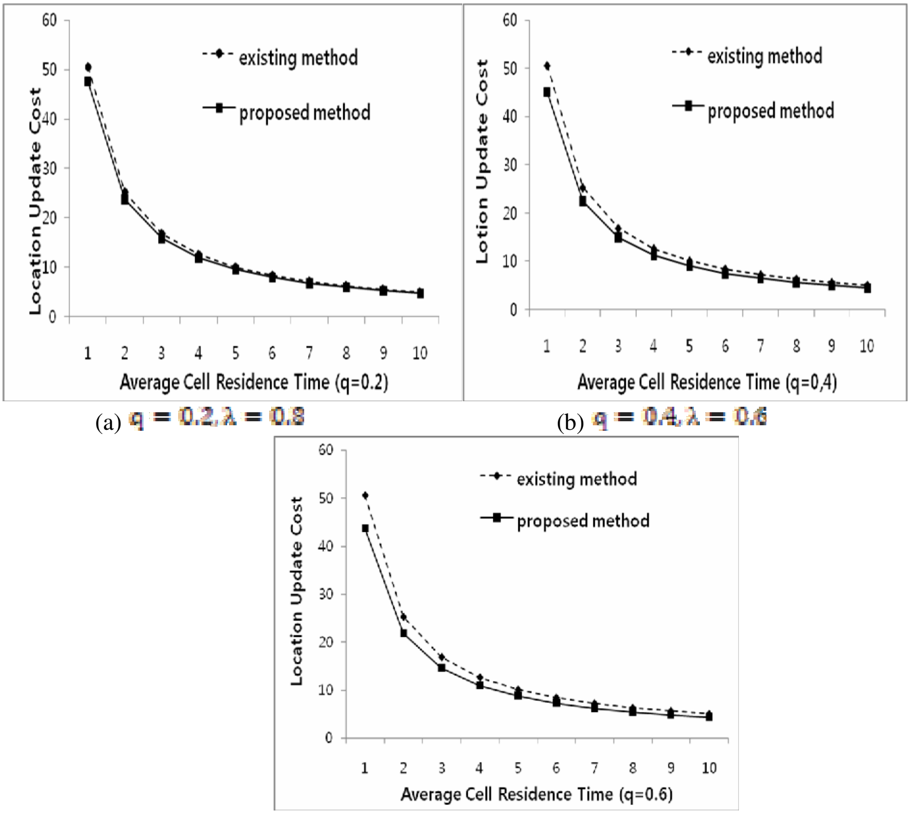
5 Numerical Results

In this section, we provide some numerical evaluation to demonstrate the performance of proposed scheme as compared with existing method. The parameter values for the analysis are referred from [16], [17] and [18]. They are shown in table 1.

Table 1. Numerical simulation parameter for performance analysis

Parameter	α	β	τ	κ	DHA-ACR{1,2}	DCN-ACR{1,2}	DRAS{1,2,3}-MN	DACR{1,2}-RAS{1,2,3}
value	0.1	0.2	1	2	8	6	1	2
Parameter	DHA-CN	N_{CN}	PC_{HA}	PC_{CN}	PCACR	DACR1-ACR2	λ_1	λ_2
value	6	2	24	6	10	1	0.1	0.2

Fig. 5 shows the variation in the location update cost as the average cell residence time is changed in the random-walk model. In a comparison of our proposed scheme with the existing method, our proposed scheme reduces the location update cost from 16% to 8% approximately.



(a) $q = 0.2, \lambda = 0.8$

(b) $q = 0.4, \lambda = 0.6$

(c) $q = 0.6, \lambda = 0.4$

Fig. 5. Location update cost as function of average cell residence time of MN

6 Conclusion

The proliferation of the internet services with provision of a variety of multimedia content, as well as demand for portable internet service via various mobile terminals such as notebook PC, PDA, and cellular phone is increasing rapidly. However, current roaming procedures are very slow and unstable when we use real-time applications. In this paper, our work focuses on mobility based on the WiBro. We distinguish BU priority in ACR. The performance analysis and the numerical results presented in this paper show that our proposal has superior performance compared to the existing method. The proposed scheme reduces the location update cost by more than 15% approximately.

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