Efficient Network Management based on Fast Fault Discovery for Indoor WiBro System

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Abstract

Indoor WiBro system, which is gaining attention as the efficient alternative of WLAN, is promising to expand coverage and improve system performance in the indoor environment. Main framework of indoor WiBro system is based on the existing outdoor WiBro system [1], however more optimized for indoor requirements such as static channel characteristics, low mobility, and high data rate applications. For the indoor WiBro system, network management is quite important issue for improving efficiency. However, the network architecture of indoor WiBro system is different from that of the existing outdoor WiBro system. Therefore, we propose an efficient network management scheme optimized for indoor WiBro system. The proposed network management scheme improves the performance of indoor WiBro system and reduces the overhead for managing network through fast fault discovery and efficient compensation, which provides QoS and minimizes interference.

I. Introduction

WiBro (Wireless Broadband) is a wireless broadband Internet technology developed by the South Korean telecommunication industry. WiBro is the South Korean service name for the IEEE 802.16e (mobile WiMAX) international standard. It adapts TDD for duplexing, OFDMA for multiple access and 8.75 MHz channel bandwidth [1]. It was devised to overcome the data rate limitation of mobile phones (for example CDMA 1x) and to support mobility to broadband Internet access (for example ADSL or Wireless LAN). In February 2002, the Korean government allocated 100 MHz of electromagnetic spectrum in the 2.3 - 2.4 GHz band, in late 2004 WiBro Phase I was standardized by the TTA of Korea and in late 2005, the IEEE reflected WiBro as the IEEE 802.16e (mobile WiMAX).

WiBro system operates in a quite high frequency(2.3 - 2.4 GHz), which makes it hard to communicate over long distance and in NLOS(non-line of sight) channel. Due to the bad propagation characteristic, the electromagnetic wave can not efficiently penetrate obstacles such as a wall and a partition in the indoor environment. It causes large path loss. Thus, when it comes to the indoor environment in which there are many obstacles and NLOS channel, the system throughput of WiBro system would be very limited. Also, compared to outdoor cellular WiBro system, system requirements for indoor system are discriminated with respect to many aspects such as QoS, data rate, and mobility. If the specification of WiBro is well-modified for the indoor environment, system performance can be improved. On the other hand, it means that the existing WiBro system can not be directly applied to the indoor environment such as home and office.

Therefore, the demand for high performance in wireless communication has led into intense efforts towards the research and development of an efficient indoor WiBro system in industrial and academic fields. Indoor WiBro system mainly aims at outperforming WLAN system to take occupancy of indoor system market share. Recently, many telecommunication companies and universities are making a struggle to develop and standardize an indoor WiBro system. In developing indoor WiBro system, network management is one of the most important issues. In this paper, we state the difficulties in implementing the network management function of the indoor WiBro system, and propose an efficient network management scheme to overcome the stated problems.

In this section, the overall description of WiBro system in Korea is presented. In section II, we explain the problems of the conventional network management protocol, when it is applied to indoor WiBro system. To overcome the problems given in section II and to improve the system performance, we propose an efficient network management scheme for the indoor WiBro system in Section III. Simulation results to show the performance of the proposed scheme are followed in section VI. Finally, concluding remarks are described in section V.

II. Network Management in WiBro System

In the existing outdoor WiBro system implemented by KT in South Korea, WiBro NMS(Network Management System)
and WiBro EMS (Element Management System) are devised for network management. WiBro NMS provides efficient management functions to control system equipment such as ACR (Access Control Router), RAS (Radio Access Station), switch, and repeater by using SNMP (Simple Network Management Protocol). Also, to promote efficiency, WiBro EMS operates as the agent of WiBro NMS, which provides mediation device for managing a group composed of an ACR and RASs attached to the ACR. The layered architecture for network management is shown in Fig. 1.

The layered architecture for network management can not be directly applied to indoor WiBro system because the network architecture of indoor WiBro system is not the same as the network architecture of the existing outdoor WiBro system. The network model of indoor WiBro system is shown in Fig. 2.

Indoor WiBro system is supposed to be deployed in home and office. In this case, each indoor RAS can construct its own private network (Femto cell). Usually, indoor WiBro network in home environment does not even contain ACR. The RAS of indoor WiBro takes over some essential functions of ACR instead. Also, there can exist an simplified ACR in the indoor WiBro network, namely pico-ACR, in office area. However, the functions of a pico-ACR are very different from those of the existing ACR in outdoor WiBro system. Therefore, if we directly apply the existing layered architecture for network management to indoor WiBro system, each RAS in home and each ACR in office should have their own WiBro EMS agent function for network management. It generates huge overhead in deploying the network management function of indoor WiBro system.

III. MODELLING AND ANALYSIS OF PROPOSED NETWORK MANAGEMENT FOR INDOOR WI-BRO SYSTEM

In this section, we introduce the efficient fault reporting scheme of an indoor RAS without deploying WiBro EMS agent function for each indoor RAS. Also, an network management system should minimize damage caused by the fault through an efficient fault compensation algorithm, which minimizes the interference and provides a seamless connection for the users of indoor WiBro system.

A. Backward Diagnosis algorithm

Fault discovery should be performed as soon as possible to cope with the bad situation immediately. As explained above, WiBro EMS agent function can not be deployed for each indoor RAS because of too much overhead. Even though WiBro EMS manager can not manage each indoor RAS, the fault of indoor RAS can be reported by using neighbor RAS in our proposed scheme. Fig. 3 shows an example. Abnormal disconnection can occur due to a fault in wireless link or wired link. A fault in wired link between indoor RAS and a router can be perceived by using an existing network management protocol. However, a fault in wireless link between MS and indoor RAS can not be detected without WiBro EMS function. In the proposed scheme, the fault of indoor RAS is not directly reported to WiBro NMS, rather reported though a neighbor RAS along an indirect path. That is why we call this backward diagnosis algorithm.

The proposed backward diagnosis algorithm is implemented by modifying a message which is used for network entry procedure. When an indoor RAS is corrupted, an MS within the coverage of the corrupted RAS should carry out network entry procedure to keep the connection. Network entry procedure contains registration procedure. During registration procedure, the MS which existed within the coverage of the corrupted indoor RAS sends an RNG-REQ message to a neighbor RAS.
to request registration. We modify the RNG-REQ message to notify the fault of the indoor RAS. If the service session of an MS is disconnected abnormally, the MS marks up the fault record on the RNG-REQ message as shown in Fig. 4. The abnormal disconnection is defined as an event that the received signal strength becomes almost zero unpredictably, which can be caused by the fault of RAS, power off, a disconnection of wired link, etc. In case of abnormal disconnection, the MS sets TLV type 18 as 1 and writes down the ID of the corrupted RAS into TLV type 19 field as shown in Fig. 4.

Two TLV fields are devised to report the fault of a corrupted indoor RAS. Using the modified RNG-REQ message, the MS which was included in the coverage of the corrupted RAS notifies the neighbor RAS. Upon receiving this information, the neighbor RAS notifies the fault of indoor RAS to WiBro NMS. Then, WiBro NMS tries to temporarily compensate and fix the fault. An efficient compensation algorithm for indoor WiBro system is followed.

B. Fault compensation for indoor WiBro system

The indoor environment is usually in interference-limited situation, which means the effect of interference is much larger than the effect of white gaussian noise. Thus, SINR is determined largely by the ratio of the received signal to the inter-cell interference. The effect of noise is relatively negligible. In this situation, to maintain providing QoS for other indoor WiBro users and to compensate the fault of corrupted RAS in the indoor environment, it is an efficient way that the other normal indoor RASs increase the transmission power at the same time. It does not degrade the performance of other indoor WiBro users, because the signal power and interference of an MS increases equally.

In our proposed scheme, indoor RASs should increase their transmission power if an indoor RAS is broken. We assume that the transmission power of indoor RASs is increased equally so that every indoor RAS has the same transmission power level. By increasing transmission power equally, the SINR of the other indoor users in the coverage of normally operating indoor RASs can be maintained. The main objective of the power adapting algorithm is to minimize the interference to outdoor RASs while maintaining the minimum SINR level of an MS higher than threshold $\text{SINR}^{thr}$, because the increase of transmission power will increase the interference to outdoor RASs. Optimal power can be found by solving the problem formulated below:

$$
\begin{align*}
\text{minimize} & \quad \sum_{A \in R} \sum_{j \in U} P_t \cdot (PL_j(A))^{-1} \\
\text{subject to} & \quad \min(SINR_i) \geq \text{SINR}^{thr}, \\
& \quad P_{\text{initial}} \leq P_t, \quad 0 \leq i \leq N, \quad j \in U
\end{align*}
$$

where $P_t$ means the transmission power of indoor RASs, $\text{SINR}_i$ means the average SINR of an MS $i$, $PL_j(A)$ means the pathloss of an indoor RAS $j$ at a point $A$, and $R$ is the set of the locations of outdoor RASs. And $N$ means the number of MSs and $U$ means the set of indoor RASs which are not broken. Moreover $P_{\text{initial}}$ means the initial power of indoor RASs.

We can change the object function of eq.(1) by using the fact that $PL_j(A)$ is not changed by $P_t$. The objective function can be changed as follows:

$$
\text{minimize} \quad P_t
$$

Let $i$ be the point where $\text{SINR}_i$ is minimized and $i$ be in the coverage of an indoor RAS $k$. Then constraint in eq.(1), can be changed as follows:

$$
\frac{P_t \cdot (PL_k(i))^{-1}}{N_0 B + P_t \sum_{j \in U_{\text{in}}} (PL_j(i))^{-1}} \geq \text{SINR}^{thr}
$$

where $U_{\text{in}} = U - \{k\}$.

Let the first constraint of eq.(1) be $g(x)$. Then the first derivative and second derivative can be written as follows:

$$
\begin{align*}
g(x) &= \text{SINR}^{thr} - \frac{P_t \cdot (PL_k(i))^{-1}}{N_0 B + P_t \sum_{j \in U_{\text{in}}} (PL_j(i))^{-1}} \\
\frac{\partial g(x)}{\partial N_t} &= -\left(\frac{1}{(N_0 B + P_t \sum_{j \in U_{\text{in}}} (PL_j(i))^{-1})^2}\right) \\
\frac{\partial^2 g(x)}{\partial N_t^2} &= \frac{2 \left(\sum_{j \in U_{\text{in}}} (PL_j(i))^{-2}(N_0 B + P_t \sum_{j \in U_{\text{in}}} (PL_j(i))^{-1})\right)}{(N_0 B + P_t \sum_{j \in U_{\text{in}}} (PL_j(i))^{-1})^3} \geq 0
\end{align*}
$$

where fourth inequality holds because $PL_j(i)$ and $N_0 B$ are positive values. From eq.(4), we can find that the constraint $g(x)$ is convex. Since an objective function and other constraint are affine functions, the problem eq.(1) is convex problem and a point which satisfies a KKT condition is an optimal solution [3].

Next, we find the optimal solution of eq.(1) by finding a point which satisfies KKT condition. The optimal solution of
eq. (1) should satisfy following KKT conditions:

\[
\frac{\partial L(\lambda, \mu)}{\partial P_t} = 1 - \lambda \left( \frac{N_0 B + P_t}{\sum_{j \in U_{in}} (P L_j(i))^{-1}} \right)^2 - \mu \\
0 = \lambda (SINR^{thr} - \frac{P_t}{N_0 B + P_t \sum_{j \in U_{in}} (P L_j(i))^{-1}}) \\
0 = \mu (P_{initial} - P_t) \\
0 \leq SINR^{thr} - \frac{P_t}{N_0 B + P_t \sum_{j \in U_{in}} (P L_j(i))^{-1}} \\
0 \leq P_{initial} - P_t \\
0 \leq \lambda, \mu
\]

Then, the solution of eq. (5) can be easily found as follows:

\[
P_t = \max\{P_{initial}, \frac{SINR^{thr} - N_0 B}{(P L_k(i))^{-1} - SINR^{thr} \sum_{j \in U_{in}} (P L_j(i))^{-1}}\}
\]

Since \(P_t\) in eq. (6) satisfies KKT conditions, it is an optimal transmission power of an indoor RAS.

By using eq. (6), we can find the optimal transmission power of indoor RASs. From eq. (6), we can find the maximum achievable value of \(SINR^{thr}\) by using the fact that the denominator of eq. (6) is larger than zero. The maximum achievable value of \(SINR^{thr}\) can be written as follows:

\[
SINR^{thr} \leq \frac{(P L_k(i))^{-1}}{\sum_{j \in U_{in}} (P L_j(i))^{-1}}
\]

IV. NUMERICAL RESULTS AND DISCUSSIONS

In this section, we evaluate the performance of our proposed scheme compared to the conventional scheme. In the performance evaluation, we consider simple power control scheme which increases the power of all indoor RASs by the same amounts. From the performance evaluation, we can see that although we only consider the simple power allocation scheme, our proposed scheme shows large system gain compared to the conventional scheme.

In this section, we assume that indoor RASs are positioned as shown in Fig. 5. And we assume that only one of the indoor RASs can be broken and we can detect the broken indoor RAS by using our proposed scheme. We use the NLOS WINNER model for pathloss, [2] and we do not consider shadow fading and multipath fading. We assume that the interference from outdoor RAS to indoor RAS is -76dBm and we also assume that the frequency reuse of indoor RAS and outdoor RASs is one. Moreover, we assume that the normal transmission power of the indoor RAS is 100mW and the maximum transmission power of the indoor RAS is 100mW. In the performance evaluation, we calculate the cumulative density function (CDF) of the SINR of MSs, the mean and the minimum SINR of the MSs.

First, we calculate the CDF of the SINR of MSs which were in the coverage of a broken indoor RAS. We calculate the CDF by varying \(SINR^{thr}\) from -9dB to -6dB. The CDF is shown in Fig. 6.

As we can see from the figure, the CDF of the SINR of MSs shifts to the right as \(SINR^{thr}\) increases, because by increasing \(SINR^{thr}\), the transmission power of indoor RASs is increased and therefore the overall SINR of MSs which were included in the coverage of a broken indoor RAS is increased.

But from this figure, we can also see that the CDF graph converges as \(SINR^{thr}\) increases. There are two reasons for convergence. First reason is that the transmission power of an indoor RAS is limited to 100mW. And second reason is that as the transmission power of the indoor RAS increases, the system becomes more like an interference limited system. In the interference limited system, when the transmission power increases, the interference from other indoor RASs increases too, and eventually the SINR of the MSs is unchanged regardless of the increase of the transmission power of the indoor RASs. We can also find that the minimum SINR increases as \(SINR^{thr}\) increases.

Next, we calculate the mean and the minimum SINR of the MSs which were included in the coverage of a broken indoor
RAS by varying $SINR_{thr}$ from -11dB to -8dB. The results are shown in Fig.7.

As we can see from this figure, the mean and the minimum SINR of MSs in our proposed scheme increase as $SINR_{thr}$ increases, because as $SINR_{thr}$ increases, the transmission power of an indoor RAS increases which results in the increase of the mean and the minimum SINR of MSs. On the other hand, in a conventional scheme, the mean and the minimum SINR do not change regardless of $SINR_{thr}$. As we can see, the mean and the minimum SINR of MSs are higher in our proposed scheme compared to the conventional scheme.

We can also find that the minimum SINR of MSs of our proposed scheme at certain $SINR_{thr}$ is almost coincide with the $SINR_{thr}$, because we increase the transmission power of an indoor RAS to make the minimum SINR of MSs larger than $SINR_{thr}$. So, by using our proposed scheme, the MSs which were included in the coverage of a broken indoor RAS can be effectively serviced. But the mean and the minimum SINR of MSs in our proposed scheme converge to certain values as $SINR_{thr}$ increases because the transmission power of an indoor RAS is limited to 100mW.

Next, we calculate the interference of indoor RASs to an outdoor RAS by varying the transmission power of an indoor RAS from 20mW to 50mW. We calculate the sum of the transmission power of indoor RASs at the boundary of the building in Fig.5 as the interference to outdoor RASs. The results are shown in Fig.8. From this figure, we can see that the interference increases as the power of an indoor RAS increases as we can easily expect.

V. Conclusions

For the network management of indoor WiBro system, a diagnosis scheme for fast-fault discovery and a fault compensation scheme based on optimized power control are proposed in the paper. The proposed diagnosis scheme can discover a network fault smartly with the absence of WiBro EMS agent function, and the proposed fault compensation scheme does not degrade the other indoor users and minimizes interference for outdoor users. We formulate the power control problem as non linear programming and find the optimal transmission power of indoor RASs. And from the simulation results, we show that our proposed network management schemes improves overall system performance.

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References