ABSTRACT
In this paper, we propose a wireless system discovery scheme capable of supporting effective device power management by employing a battery-efficient wireless network scanning procedure. Multi-mode terminals must be able to discover other wireless systems and, above all, to execute an inter-system handover in the heterogeneous wireless network environment. The existing methods introduced in recent research reports have certain shortcomings, such as increased battery power consumption occasioned by frequent modem activation, or the inability of the multi-mode terminal to promptly discover wireless systems. We propose a scheme in which multi-mode terminals are able to discover other wireless systems more quickly and accurately than previous schemes, while consuming minimal levels of power. We also prove that the scheme offers better performance values by comparing it with the existing schemes.

KEY WORDS
Wireless system discovery, Inter-system handover (ISHO), Heterogeneous wireless network, Multi-mode terminal, Location-Based Service (LCS).

1. Introduction
The next generation wireless communication system is aimed at providing a seamless connection that is free of interruption to service subscribers for the provision of optimum wireless systems (radio access networks) - depending on their current location and service characteristics - through interconnection among different networks, when the service domains of networks with heterogeneous characteristics are overlaid. In order to guarantee quality-of-service (QoS) without interruption to service subscribers on heterogeneous wireless networks, the system is required to support handover between different wireless networks, which is referred to as an inter-system handover (ISHO) [1][2].

Successful configuration of such heterogeneous wireless networks requires the following prerequisite conditions: First, it is essential to configure a managed core network, which may provide a QoS guaranteed seamless handover to service subscribers who move between interoperating wireless systems. Second, a mobile terminal needs to be configured with either multiple modem-interface modules or an SDR-based (Software Defined Radio) reconfigurable system in order to access the different wireless networks in heterogeneous wireless networks. In this paper, it shall be referred to as a multi-mode terminal (MMT) [2]. Radio access to the different wireless systems, ISHO registration and Mobile-IP procedures are required in order to execute an ISHO on heterogeneous wireless networks. The following three key technologies should proceed in sequential order before such an ISHO procedure is performed:

- **Wireless System (RAN) Discovery**
The MMT must be able to detect all wireless systems that are accessible at the current location quickly and accurately. To enable this, the MMT modem-interfaces need to be activated. However, the battery consumption of the MMT should not be sharply increased by the MMT modem-interfaces activated to scan the wireless systems.

- **Optimal Wireless System Selection**
The MMT needs to select the most appropriate wireless system from among all the accessible wireless systems. Selection should be determined by considering such factors as the data transmission rate, service charge, battery consumption, and the wireless system’s current status, depending on the type of services currently being used by the subscriber.

- **Determination of ISHO Execution Start Point**
This is the point in time when ISHO execution actually starts, after the most appropriate wireless system has been selected from among those wireless systems which have
been discovered. The ISHO execution start-point should be determined so as to minimize the ping-pong effect, considering the speed of MMT, the movement pattern of MMT, and the service area of the wireless system to access.

This paper deals with a scheme to effectively discover wireless systems from among the three prerequisite key technologies only for the ISHO mentioned above. To that end, we propose a scheme that discovers wireless systems quickly and accurately, while minimizing the battery consumption of MMT.

2. Related Works

Fig. 1 shows an example of heterogeneous wireless networks where a hot-spot region is created with multiple micro cells within a macro cell.

Two factors are of the utmost importance when considering the way by which an MMT, which is served by a macro cell in the heterogeneous wireless networks, recognizes its entry into a hot-spot region: The first requires the MMT to recognize the wireless system that serves the hot-spot region fast and accurately. The second means preventing the MMT from excessively consuming battery power. Thus, there is a trade-off between battery efficiency and the wireless system discovery time.

The simplest method by which the MMT can discover multiple wireless systems consists of allowing it to monitor the wireless systems constantly, with all of its modem-interfaces activated at all times. The MMT, which is served by a macro cell as shown in Fig. 1(a), can detect the real coverage of the hot-spot region when it moves into a hot-spot area. However, this scheme raises a problem, as the battery consumption of the MMT will increase sharply because all of its modem-interfaces are continuously activated.

The following approaches have been proposed thus far to address the problem of excessive MMT battery consumption, so as to discover wireless systems in the above scheme:

The first scheme involves detecting the signal strength of heterogeneous wireless systems by having the MMT modem-interfaces activated at a regular interval. In this case, the battery consumption of an MMT shows a marked decrease when the modem-activating frequency is extended. However, the MMT cannot discover the wireless systems quickly and accurately. Conversely, the MMT can discover the wireless systems quickly and accurately when the modem-activating frequency is shortened, although the battery consumption will increase excessively.

The second scheme is to practical use a Location-Based Service (LBS or LCS) server, which informs the MMT of the service available area of multiple wireless systems together with its location information, required to detect accessible wireless systems, while preventing its modem-interfaces from being activated too often, as much as possible. This termed an adaptive system discovery scheme in paper [3]. The notion is based on the basic premise that the MMT is integrated with a geo-location technology such as GPS (Global Positioning System) [4]. The scheme is designed to minimize unnecessary modem-interface activation by shortening the modem-activating frequency when the MMT enters an ideal coverage setting for the hot-spot area, as shown in Fig. 1(b), because the hot-spot area’s real coverage is variable. When it is assumed that the hot-spot region is within an urban area and a WLAN system is supported, however, the service coverage provided by one or more access points (APs) will not form a circle or hexagon, which is the conceptual diffusion model. Therefore, the battery consumption of
the MMT and its fast and accurate discovery of multiple wireless systems depend on how the ideal coverage is set up.

In the paper, we propose a scheme that enables the MMT to discover multiple wireless systems quickly and accurately, while minimizing unnecessary modem-interface activation, by changing the ideal coverage adaptively in real time when the real service coverage of the hot-spot area varies, while the ideal coverage is configured in a similar form to the real coverage, as shown in Fig. 1 (c). This is referred to as a network-assisted system discovery (NASD) scheme in this paper.

3. Network-Assisted Wireless System Discovery Scheme

The network-assisted system discovery (NASD) scheme proposed in this paper refers to the information combined with the signal strength values of the overlaid wireless systems obtained at the current location of the MMT, as well as the position of the MMT. In other words, the scheme proposed in this paper does not set the ideal coverage in a fixed range, as shown in Fig 1 (b). Instead, the ideal coverage proposed in this paper is configured similarly to the real coverage by considering the signal strength of individual wireless systems depending on the geo-location of the heterogeneous wireless networks. To achieve this, the NASD scheme is effected through the following processes:

1) The signal strength of wireless systems stored on the reference points of an LCS server

First of all, it is necessary to configure reference points on the LCS server. These reference points are configured in a lattice shape in this paper, as shown in Fig. 1 (c). The ID of the wireless system and its signal strength received at the current location are kept in a reference point. The information stored in the reference point is processed using the following procedures: The signal strength values of the wireless systems measured when an MMT’s power is turned on and all its modem-interfaces are activated are transmitted to the LCS server through a selected wireless system along with their ID and the position information of the MMT. Upon receiving such reference information, the LCS server assigns the reference point nearest to the current location of the MMT and saves the data received at the reference point after averaging it with the existing information.

2) Generation of an adaptive ideal coverage by the reference points

The ideal coverage of the hot-spot region is generated by connecting the reference points with an average signal strength that is greater than the ISHO acceptable threshold (A-TH) value, as shown in Fig. 1 (c). The ISHO acceptable threshold (A-TH) should be a value smaller than the ISHO signal-strength threshold (SS-TH), referring to a signal strength that is sufficiently strong for the MMT to perform ISHO into the hot-spot region. The difference between the A-TH and SS-TH will be determined considering the reference point interval with the error tolerance scope of the position of the MMT obtained using the geo-location technology. (The adaptive ideal coverage will be closer to the real coverage when the reference point interval is narrower and the geo-location data is more accurate.)

3) Transmission of the adaptive ideal coverage map to all MMTs located within a macro cell

4) Activating the MMT modem-interface which enters the adaptive ideal coverage

When the MMT, which intends or is enabled to perform ISHO, enters the adaptive ideal coverage, the MMT receives the signal of the wireless system by activating its modem interface. If the received signal strength is greater than SS-TH, the wireless system is discovered. If the received signal is weaker than SS-TH, the strength will be monitored again after a given interval.

The proposed scheme can discover multiple wireless systems quickly and accurately while preventing the MMT modem interfaces from being activated too often through the above processes. This paper also proves through performance evaluations that the NASD scheme performs more effectively than the existing schemes.

4. Simulation

The performances of the NASD scheme proposed in this paper are compared with those of existing schemes - such as the ‘always modem-activating scheme’, the ‘periodically modem-activating scheme’, and the ‘adaptive system discovery scheme’.

In the simulation for this study, a cell layout is a base environment constituted by seven micro cells (hot-spot region) that are well-arranged within a macro cell to ensure the simulation has simplicity and fairness, as
shown in Fig. 2. The simulation employed a wrap-around scheme to minimize the boundary effect of the MMTs that escape the macro cell displayed in a hexagonal form. When any of the MMTs escape the boundary of a macro cell, they are made to connect to the opposite side of the simulation map. In order to ensure a practical radio propagation environment within the simulation map, we employed a radio propagation model (log-normal shadowing model) that considers path-loss and shadowing. If we use the path-loss + shadowing formula that is widely adopted for ns-2 network simulators [5], the model formula will be as follows:

\[
\left( \frac{P_r(d)}{P_r(d_0)} \right)_{dB} = -10\beta \log \left( \frac{d}{d_0} \right) + X_{dB}
\]

where \(X_{dB}\) is a Gaussian random variable with zero mean and standard deviation one. In the simulation, the radio propagation model [6] is used to predict the received signal power \(P_r(d)\) at distance \(d\).

Table 1 shows some important parameters adopted in the simulations to evaluate the performance of the proposed scheme. The following metrics are used to evaluate the performance of the proposed NASD scheme:

1) **Sampling of MMT’s wireless system discovery point**
   In this paper, it is assumed that the MMT will discover a wireless system when the signal strength received by the MMT by activating its modem is greater than SS-TH. We sample the location point of the MMTs when the MMT discovers a wireless system of the hot-spot region. We may intuitively recognize how fast and accurately each scheme discovers the wireless system by the discovery point sampling distribution diagram.

2) **Average wireless system discovery time after entering the ideal coverage**
   This refers to the time taken from the MMT’s entry into the ideal coverage of the adaptive system discovery scheme to its discovery of the wireless system. Using this, we may quantitatively determine the rapidity with which the MMT discovers the wireless system in the actual wireless network environment. This metric has a significance similar to that of the first metric.

3) **Average number (frequency) of modem interface activating**
   This represents the number of times the modem is activated during the period from the time when the MMT is first generated in a macro cell (out of the hot-spot domain) to the time when the MMT discovers the wireless system of the hot-spot region. We may estimate the power consumption rate of the MMT. We excluded the ‘always modem-activating scheme’ and the ‘periodically modem-activating scheme’ from this metric.

Fig. 3 shows a sampling distribution diagram of the location-point at which the MMT first discovers the hot-spot domain wireless system. These diagrams show only a part of a hot-spot cell. From these diagrams, we may...
intuitively recognize that the ‘always modem-activating scheme’ discovers the hot-spot region more quickly and accurately than other schemes. The figure also shows that the system discovery points of the proposed NASD scheme are most similar to those of the ‘always modem-activating scheme’. This proves that the adaptive ideal coverage of the NASD scheme is similar to the real coverage.

Fig. 4 shows the average amount of time measured from the MMT’s entry into the ideal coverage of the adaptive system discovery scheme to its discovery of the hot-spot cell. From this figure, we are able to recognize that the NASD scheme is capable of discovering the hot-spot wireless system considerably faster than either the ‘periodically modem-activating scheme’ or the ‘adaptive system discovery scheme’.

Fig. 5 shows the average frequency of MMT modem interface activation from the MMT’s entry into the ideal coverage of the adaptive system discovery scheme to its discovery of the hot-spot cell. We compared the frequency between only the NASD scheme and the existing adaptive system discovery scheme. The figure shows that the NASD scheme reduces the modem-activating frequency by approximately 50% when compared with the adaptive system discovery scheme.

Furthermore, the figure also shows that the performance of the adaptive system discovery scheme varies as SS-TH, determining the start point of ISHO. However, the performance of the NASD scheme does not vary even though SS-TH changes, thereby indicating that the performance is hardly affected by changes in the service scopes of the hot-spot region. Therefore, this result implies that the same performance will be maintained even when the hot-spot region service section has irregular shapes (though the simulation for this study is based on a cell layout consisting of seven well-arranged cells).

Through performance evaluation, it has been ascertained that the proposed NASD scheme discovers the wireless system faster, while reducing the power consumption of the MMT, compared to the previously existing schemes designed to discover the wireless systems.

5. Conclusion

In this paper, we propose a NASD scheme that may efficiently discover the hot-spot region using the adaptive ideal coverage concept. The NASD scheme reduces power consumption by preventing an MMT from activating modem interfaces excessively. It also reduces the total ISHO execution time required for the MMTs to perform ISHO, as it enables them to discover wireless systems with speed and precision. As such, the proposed NASD scheme is designed to address the weak points of the existing schemes by ensuring both the ISHO execution time and power efficiency, which have a trade-off relationship. Additionally, it is expected that the NASD scheme will demonstrate high performance in a hot-spot region characterized by irregular service coverage.

References