Contention vs. Polling in wireless high-bit-rate packet transfer for fast movers in connected micro-cells

Phan Thanh Hoa
Dept. of VLSI System Design
Ritsumeikan University
1-1-1 Nojihigashi, Kusatsu-shi, Shiga-ken, 525-8577 Japan
gr023015@ed.ritsumei.ac.jp

Takahiko Yamada
Dept. of VLSI System Design
Ritsumeikan University
1-1-1 Nojihigashi, Kusatsu-shi, Shiga-ken, 525-8577 Japan
tyamada@se.ritsumei.ac.jp

Abstract - For high-speed packet transfer in the wireless environment, the shared radio medium is provided to mobile terminals (MT) through the control of MAC layer. Contention and polling technique are known as two fundamental methods that are used in this environment. This paper aims to compare the operation of these two methods if they are enhanced to use in a connected micro-cells system to support for high-bit-rate packet transfer for fast movers. Consider them in capability of offering smooth handover in term of maintaining handover latency, guaranteeing acceptable delay for multimedia traffic, transmitting over randomly varying wireless channel, the authors realize that polling technique can satisfy these demands but not contention. According to this analysis, we propose the multi polling and virtual single cell to make packet transfer from/to MT to BS (base station) even during handover kept in a stable condition without latency. To create the virtual single cell, we configure an LMC (Logical Macro-Cell) which groups several adjacent micro-cells and the serving cell into the same multicast tunnel. BS of each LMC sends polling packet with the same sequence number to the identical target terminal and the target terminal responds only to the BS of the micro-cell where it stays. Mobile terminal (MT) can conduct packet transfer if it stays in the LMC in spite of quick cell-to-cell move. The LMC is switched over to the next LMC when the MT moves to another micro-cell. Two LMCs can be a virtual single cell since LMC switchover occurs when the target terminal stays in a cell shared by two adjacent LMC. To do so, the total micro-cells in which the target terminal moves as if they are virtually single cell for the target terminal, and this allows high-bit rate packet transfer to fast terminals. Our simulation results outperform in handover latency though somewhat overhead induced.

Keywords- Contention, Polling, connected micro-cells , Logical Macro-cell, multi polling.

I. INTRODUCTION

Future mobile network system can be seen as Fig.1 in which essential component network for mobile terminals will fall in three types : macro-cellular network provides all kinds of services for general mobile terminals, connected micro-cells network offer special high-speed services for vehicular users and stationary terminals can use high-speed connection from broadband wireless network as Hotspots. Macro-cell network system with large coverage area is designed to offer mobility support to fast movers and general mobile terminal. In these systems, the handover frequency is relatively low but inefficient use of the limited wireless resources limits the data transmission rate for the users and large coverage reduces number of mobile users in specific area. With the realization of 3G and the evolution of broadband mobile network such as WiMAX [3], HSDPA (High-speed Downlink Packet Access) [4] have lead to multimedia services with mobile terminals. However, the large coverage of their macro-cell based makes less offer large number of mobile terminals meanwhile the demand of multimedia applications for normal and vehicular users have been increased. Together with the development of such a macro-cell network, the popularization of Wireless LAN (WLAN) technology has given us high-speed wireless Internet access at fixed hotspot locations. The author are therefore of the opinion that the requirements towards an integrated networks offering high data rates over a wide area to many kinds of terminals, including fast movers, will increase significantly as multimedia services in the fixed networks continue to increase in popularity. To offer true mobile multimedia applications for high-speed mobile terminals, integration into micro-cells is therefore a necessity in spite of the mobility processing difficulties.

To transfer high-speed data packet in radio channels of broadband wireless network such as WLAN, contention and inefficient use of the limited wireless resources limits the data transmission rate for the users and large coverage reduces number of mobile users in specific area. With the realization of 3G and the evolution of broadband mobile network such as WiMAX [3], HSDPA (High-speed Downlink Packet Access) [4] have lead to multimedia services with mobile terminals. However, the large coverage of their macro-cell based makes less offer large number of mobile terminals meanwhile the demand of multimedia applications for normal and vehicular users have been increased. Together with the development of such a macro-cell network, the popularization of Wireless LAN (WLAN) technology has given us high-speed wireless Internet access at fixed hotspot locations. The author are therefore of the opinion that the requirements towards an integrated networks offering high data rates over a wide area to many kinds of terminals, including fast movers, will increase significantly as multimedia services in the fixed networks continue to increase in popularity. To offer true mobile multimedia applications for high-speed mobile terminals, integration into micro-cells is therefore a necessity in spite of the mobility processing difficulties.

General mobile terminals

Macro-cellular networks

Fast mobile terminals

Connected micro-cells

Stationary terminals

Hot spots

Fig.1 Future mobile network system
polling are fundamental mechanism widely used. However, because these mechanisms are efficient in the range of one cells but not support mobility between different cells thereby they do not maintain continuous connections of mobile users during handover.

This paper analyzes the contention and polling mechanism when they are applied to use in the connected micro-cell network for fast moving terminal where the quick response during handover is required in very short time due to small overlapping areas of two micro-cells. From this analysis, the authors propose the multi-polling method in a virtual single cell to enable fast handover process for fast movers in a connected micro-cells environment.

II. NECESSITY OF MICRO-CELL SYSTEM TO OFFER MOBILE MULTIMEDIA SERVICES

Traditional cellular networks are usually designed to offer mobility support to fast movers, and are therefore constructed with macro-cells. In these systems the handover frequency is relative low, but inefficient use of the limited radio resources limits the data transmission rate for the users. To offer true mobile multimedia services, integration into micro-cells is therefore a necessity to increase the capability in providing rich radio resource in spite of the mobility processing difficulties.

In order to show advantages of connected micro-cell system in providing much radio resources, we compare the radio resource capacity between two types of micro-cellular networks: one is a unified microcellular network, and another is the conventional double-tier network, where a macro-cell is overlaid on a group of micro-cells.

For simple comparison, assumption that there are N micro-cells overlaid by one Macro-cell in the double-tier network. The unified microcellular network consists of N micro-cells in which M cells serving for fast movers and (N-M) micro-cells used for normal mobile users. Macro-cell in the double-tier network cover the same area that M micro-cells in the unified micro-cell networks does as shown in Fig.2(a).

To provide same amount of radio resources for vehicular users that the unified micro-cell network does, the macro-cell of the double-tier configuration must accommodate the total

![Diagram](attachment:image.png)

Fig.2 Macro and microcellular network

traffic of $M$ micro-cells in the unified micro-cellular network. Therefore, from Fig.2(b) we can estimate that the required volume of radio resources of the macro-cell should be almost $pM$ times larger than that of the unified micro-cellular network. Here, $p$ is the average resource usage because all micro-cells do not work at their full load.

The capacity of the unified micro-cellular network increases if the macro-cell is removed and its resources are redistributed to one of the micro-cells. The macro-cell can be removed if the unified micro-cellular network supports quick handover. In this case, the network capacity of the unified micro-cellular network can be $pMN/s$ larger than that of the macro-cell in the double tier configuration. Here, $s$ is the number of sector, and resource reuse factor is assumed to be identical between both macro- and micro-cell configurations. For example, to cover the 5km-coverage of one Macro-cell, in MM-MAN, 10 micro-cells ($M$) with 300meter-diameter need to be installed continuously along the roads. Assumption that the average resource usage coefficient in these micro-cell is $p = 0.4$ so the amount of radio channels that each micro-cell can provide is 400 times larger than one Macro-cell does.

III. CONTENTION VS. POLLING FOR FAST MOVING TERMINALS IN MICRO-CELLS NETWORK

Contention and polling mechanism are fundamental methods to transfer data packets in the wireless network like WLAN. If these techniques are applied to use to support mobility in the connected micro-cells network, they need to be discussed. A connected micro-cells network is a mobile network in which all BSs are connected to a central control node that has a role of control and distribute information to ach of BS. Coverage of each micro-cell is mutual overlap and creates a continuous coverage area to support for mobility of mobile users. This section, therefore, gives an outlook of some aspects of these methods.

A. Conversation in a micro-cells network

1) Contention method

In this category, the entire bandwidth is provided as a single high-speed channel to be shared dynamically by the users. When a mobile terminal has data to send it first senses the channel. If the channel is idle it waits for a time interval called the DIFS (Distributed inter-frame Space) period and then samples the channel again. If the channel is still idle it transmits a data frame to the BS (Base Station). The BS waits for the time interval called SIFS (Short Inter-Frame Space) time and replies with an ACK for data. A station that senses the channel to be busy must defer until the medium is free. Since multiple stations could have been waiting for access, there is a higher probability of collisions immediately after the medium becomes free. A wireless medium does not allow for collision detection through power measurement and the hidden problem when many mobile terminals are out of their transmission range with each other increases the collision ratio.

In order to reduce collisions during this period, a station must generate a random back-off time for collision avoidance (CA), which is an additional interval represented by Contention Window (CW) beyond the DIFS time that the station must
monitor the delay of data packet transfer for each MT. For through polling message, the polling technique can control and the next MT is polled. By allocating slot time for each MT goes ahead; if not, a negative reply is received by the BS and data to/from BS. When a polling message is sent to the next from a polling list maintained by BS (Fig. 3(b)). A mobile terminals. Each mobile terminal is polled sequentially by the BS for granting slot times for data packet exchange with access and recovery processes. The contention becomes inefficient in supporting mobile multimedia in a wireless environment.

2) Polling method
This method requires the presence of a central BS performing the control. The polling mechanism is controlled by the BS for granting slot times for data packet exchange with mobile terminals. Each mobile terminal is polled sequentially from a polling list maintained by BS (Fig. 3(b)). A mobile terminal that receives a poll from the BS can send or receive data to/from BS. When a polling message is sent to the next MT in sequence, and if the MT has some data to transmit, it goes ahead; if not, a negative reply is received by the BS and the next MT is polled. By allocating slot time for each MT through polling message, the polling technique can control and monitor the delay of data packet transfer for each MT. For supporting multimedia applications, polling method should be applied all the time but not contention.

With the centrally control assignment from the BS, the polling technique proves its capability in supporting sensitive time multimedia applications such as voice and video communications in microcellular network. In spite of this, the polling technique induces considerable overhead in each packet transmission cycle due to the pioneer of polling message and non-data uplink. More advantage of polling technique compared with the contention is that radio signal from different MTs is not overlapped in time that causes information destruction. This advantage is very important in the mobile network system with the central control in which large number of MTs is often geographically distributed.

B. Mobility management in connected micro-cells
It is clear that although the contention technique is efficient for packet-by-packet multiplexing in a share radio medium and mainly used in WLAN where the bursty data traffic is dominated, that the former can work well in the connected micro-cells to support true mobile multimedia services. Now, an attractive issue is to examine if the contention method is also effective in the connected micro-cells environment in which mobile terminal traverses between cells frequently.

1) Resource reservation in the core network
To focus on the performance of contention mechanism in the wireless section of the connected micro-cells network, we consider a microcellular network in which re-forwarded data packet delay from the old BS to a new BS is eliminated by resource reservation by IP multicast in adjacent BSs of the serving BS where the MT is predicted to be presence. Numerous papers have already appeared which discuss the resource reservation in adjacent cells to reduce the retransmission delay through IP multicast technique as reported in [1] and [5]. In our proposal, data packets destined to an MT are multicast to group of BS where the MT exists. In this resource reservation condition, next, we discuss the operation of contention and polling technique to understand how which one can support for mobility in the microcellular environment.

2) Problems of contention method in preloaded cells
The major difference in the operation technique of a connected micro-cells system with an independent-single cell is the capability in providing smooth handover for moving terminal that the independent-single cell does not consider. When the contention method is applied to use in micro-cells network, it can fall in some following disadvantage:

a) Large overlap of radio signal
In a shared radio medium, multi-access method is required that means any number of mobile users may access the channel of a BS at the same time, and the transmission of a signal by a user may be received over a wide area by any number of received operating at the same frequency. However, radio signals on the same carrier frequency which overlap in time may result in mutual information destruction.

b) Large latency
The contention method causes unpredictable delay of data packet transfer, especially during the handover process. The handover process has been very slow because of the fact that this network is traditionally contention-based. The reason is that it uses a fair random deferred access to the transmission medium, which introduces unbounded transmission delay due to idle time periods and retransmission due to collision. The more mobile users that are on the network the greater probability that mobile user will take an excessive amount of time to complete medium access.

c) Necessity of re-registration to notify the location
In the contention method, there is not any control information sent from the BS to MTs to monitor the location of these MTs unless when an MT requires by sending request. Although the Beacon is used at each BS to broadcast the network information to each MT in each coverage range, but the contention-based MT just go in hearing but not answer if it does have nothing to send. Therefore, the location update is informed to network when an MT re-registers. This problem is inefficient in the micro-cell environment as the mobile users
moving randomly between cell and number of buffered downward packets destined to that MT may be discards due to non-updated location.

d) Lack of QoS support

The contention method suffers from widely varying delays rendering them inappropriate to delay sensitive applications, such as voice and video communications. These deficiencies are mainly due to the use of random multiple access techniques. Particularly when an MT moving between cells with the condition of traffic unbalance, the more delay will occur as an MT moves to a heavy load because the higher collision probability with other MTs. Therefore, to maintain an acceptable delay requirement for keeping QoS of a real-time application becomes difficult for the contention technique.

C. Problem in mixed mode

According to the above analysis, the contention method should not be used for packet transfer in the connected micro-cells environment. However, polling and contention mechanism are combined in one cycle with the polling method built on the top of the contention, which provides the contention free period and beginning with the Beacon frame to inform the network information and start a mixed frame (Fig.4). If the contention is not used, the apperance of it in the frame is wasteful and the contention portion in a cycle becomes overhead and inefficient use for offering multimedia applications. Only the polling portion is kept to use for packet transfer.

D. Shifting from contention initiative to polling initiative

The contention mechanism falls in some demerits that make it operation in the microcellular network worse as described above. Otherwise, polling-based mechanism that is controlled by BS to give a mobile user a chance to access and transfer data packet can be a solution to use for the medium access in the wireless section of microcellular network. Unlike the same radio frequency signal overlapped of the contention method where mobile users access the channel at the same time due to the hidden node problem, the system with the operation of polling can detect the presence or absence of an MT due to no carrier frequency to make transition to the next MT for transmission. This ensures that each MT under the polling mechanism can be controlled to access the radio channel for packet transfer and not contend with each other. In the microcellular environment, the handover window for fast movers is very small, and the network has to handle the handovers of a large number of terminals. Therefore, for mobile multimedia applications need a QoS guarantee, the polling method proves its advantage in operation. Imaginaton of packet transfer under the contention and polling control in the preloaded cells is shown in Fig.5 and 6.

The next consideration is how to improve the polling mechanism to support smooth handover of mobile users between micro-cells. The authors propose a multi-polling and Logical Macro Cell to offer same amount of resources reserved in both wired and wireless section for mobile users before they really come to a target cell, polling mechanism can continue schedule slot assignment so terminals can do as in previous cells. It requires a group of adjacent cells work together under the same control tree.

IV. VIRTUAL SINGLE CELL OVER CONNECTED MICRO-CELLS NETWORK

In order to offer a stable service to fast movers and avoid packet loss in a connected micro-cells network, we proposed a virtual single cell LMC (Logical Macro Cell) environment to manage the mobility of users between micro-cells as if they are in a macro cell. An LMC consists of a serving cell and its adjacent micro-cells operated in the same multicast group. The LMC receives control signals and packet data from the central node through the same multicast tunnel, and works as a virtual single cell. Packets destined for fast-moving terminals are encapsulated in a multicast frame of the terrestrial network at the CN (Central Node) which determines the appropriate LMC. At the BS, the multicast encapsulation is removed before the packet is transmitted to MT over the wireless link. Packets destined for BS inside the LMC can be transmitted to the MT from all BSs in the multicast group, and the multicast group does not face the same stringent constraints on response time as an immediate handover between micro-cells. Therefore the wireless link is separated from the wired part of the network, and communication can hold on as soon as the MT tunes in to the new BS, without any signaling in the rest of the network. When the MT moves to a new cell, a new multicast group of a new LMC will be established by the decision of the CN based on the location update sent from the MT. Then the multicast transmission is transparent to the MT.
A. Multi polling in an LMC

Multi polling from micro-cells of an LMC helps the handover operation to be transparent to mobile users [6].

In the wireless link of an LMC, multi polling mechanism that we proposed is applied for all cells of the same LMC. Multi polling means a set of polls sent from a group of BSs in the same LMC. Fig.7(a) details how the multi polling mechanism works to support smooth handover for fast movers. A set of loosely synchronized polling are emitted from the BSs in the LMC where the target MT is supposed to stay. The target MT can catch the polling from one of these base stations if it stays in the LMC, to exchange packet as well as does the location update. Thus, the target MT can do packet transfer at any cell in the same LMC, and cell-to-cell move in the LMC can be neglected regardless of the velocity of MT. At the same time, the same IP address is effective in the same LMC.

It is noted that the multi polling is effective in an LMC range, so if one MT moves out of a specific group of cells, an LMC is disable that introduces a disappearance of polling signals and downward data packet is lost. Loss of polling signal in the neighboring cell causes a disruption of connection to the network.

B. Moving LMC as a virtual single cell

An LMC switchover is shown in Fig.7 (b) to ensure the reserved resources for an MT in both the wired and wireless section of the micro-cellular network whenever the MT changes to a new cell. Switchover of an LMC is conducted when the polling response is received in a sub cell. The polling response is multicast to new LMC with extended multicast manner. The central node just registers the LMC switchover to the LMC table for the MT. This procedure can contribute to reducing concentrated processing in the central node. By this way, a new LMC is created by addition of a previous serving cell, new serving cell and new target neighboring cell together with pulling out the passed cells of the old LMC. In doing so, each BS has to be declared as to belonging to a group of LMCs. Number groups of LMCs that each BS belongs to is equal to the number of cells that each LMC includes (LMC size). Each LMC is identified by a master cell that declared in the LMC table stored in the CN. The master cell of each LMC is a specific cell that is pre-defined at the installation phase of the network. For examples, the central cell of the 3-cell LMC is chosen as the master cell of an LMC. By comparing the address of the serving BS from the received polling response with the master cell, the network is able to realize whether an MT moves to new BS’cell coverage or not in order to decide an LMC switchover. LMC switchover enables multi-polling to be continued at the future target cells together with the BS change of each MT.

Operation of multi polling in an LMC makes handover process of an MT be similar to its transmission in one cell, handover time is therefore negligible.

V. PERFORMANCE EVALUATION

In this section, we evaluate the performance of the multi polling in the virtual single cell to show how our proposed methods can help the fast movers keep their high-data rate connection when they are moving in the microcellular network. We use the OMNeT++ network simulation tool [7] to simulate our performance.

A. Simulation network model

Our network simulation model consists of 10 BSs connected to the central control through Ethernet link with speed of 1Gbps. Mobile terminal moves back and forth from the first BS to the last one with a straight trajectory. LMC is multicast group controlled by the central control system. Mobile terminals exchange data packets with outer node through BSs in bi-directional communications. Inter-arrival time of data packets are followed the exponential distribution with the changeable mean value. Simulation parameters are depicted in the Table.1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of base stations</td>
<td>10</td>
</tr>
<tr>
<td>Number of mobile terminals</td>
<td>16 ~ 91</td>
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<td>Network region</td>
<td>3000m x 1500m</td>
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<td>Wireless channel rate</td>
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<tr>
<td>Transmitter power</td>
<td>10mW</td>
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<tr>
<td>Radio frequency</td>
<td>5Ghz</td>
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<tr>
<td>Cell size</td>
<td>300m</td>
</tr>
<tr>
<td>Packets size</td>
<td>1000 bytes</td>
</tr>
<tr>
<td>LMC size</td>
<td>3 micro-cells</td>
</tr>
<tr>
<td>Terrestrial network link speed</td>
<td>1Gbps</td>
</tr>
<tr>
<td>Speed of mobile terminals</td>
<td>60km/h</td>
</tr>
</tbody>
</table>

B. Handover latency

In this section, we compare the handover latency of our proposed multi polling scheme with the standard contention-
based and fast handover SyncScan scheme [2] versus the number of mobile terminals. Handover latency is defined as the time period between an MT which changes its connection from the current associated BS to a new BS.

The performance of handover latency versus number of mobile terminals which increases in the target BS when the handover MT moves at 60km/h is shown in Fig.8. Fig. 8 illustrates that the handover latency of Standard contention > SyncScan > Multi polling. This is because in the Standard Contention, an MT has to stop its connection to do scan all channels during the handover procedure and then contends with other MTs to re-register to the new BS. Otherwise, the SyncScan approach performed pre-scanning protocol before the handover procedure really happens so the delay time due to connection terminated is reduced significantly. However, even the pre-scanning protocol can eliminate the scanning delay time but after scan success the MT has to contend the medium of the new BS for re-registration, thus, handover latency is still a noticeable value. Moreover, with both the Standard contention and the SyncScan scheme, the larger the number of mobile terminals in the new BS, the longer the handover latency.

C. Throughput performance

Throughput achievements of BS and MT are considered in two cases of a single cell without multi polling and a virtual single cell with multi polling. As shown in Fig.9 throughput of BS as well as MT of the Single Cell is larger than the Virtual Single Cell. The reason is that the Single Cell does not use multi polling to handover process but contention so it is not affected by extra polling from neighboring cells. But it issues large handover latency as shown in Fig.9 due to the contention. Otherwise the Virtual Single Cell uses multi polling so in each micro-cell of an LMC it bears the overhead of polling from neighboring cells. However, as seen in Fig. 9, the difference is not much when increasing the wireless link rate. To achieve no handover latency, the Virtual single cell sacrifices small portions of its radio resources.

VI. Conclusion

This paper presented the comparison of two access methods used for shared radio medium that is contention and polling method. The purpose of this comparison is to analyze its operation to understand which one can be enhanced to apply for high-bit-rate packet transfer to fast moving terminal in the connected micro-cells network. The authors realize that the polling technique with its capability in providing slot assignment to be able to maintain acceptable delay of a connection can be used for such a network but not contention. To improve the handover process for the single polling, multi polling mechanism is proposed in a virtual single cell to support fast mobility of vehicular users. Multi polling mechanism helps vehicular users a quick response in a new cell by arranging polling frames sent frequently in neighboring cells before the MT really come in. It, therefore can offer fast mobility for vehicular users instead of contention.

Our simulation results indicated that multi polling mechanism outperforms the primary contention and SynScan fast handover scheme.

REFERENCE