A Contemporary Methodology for Bandwidth Reservation in Wireless Cellular Networks

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***Abstract*—**The emerging technologies in wireless communication under the next generation have pulled many scientists and researchers towards them. The wireless cellular network, which is a widely used technology, has various issues regarding Quality of Service (QoS). The major issues that ever attract people are resource reservation, call admission control mechanisms and user mobility patterns. In this paper, various resource reservation schemes with their unique features are discussed and compared. One of the best-suited schemes would be the Tier- Based Bandwidth Reservation Scheme with better resource utilization. The simulation results have shown the better resource utilization and conservation when compared to one of the traditional schemes. The enhancement with the bandwidth borrowing concept is also simulated and the results are compared.

***Keywords*—**Bandwidth, Mobility, Resource Reservation, Quality of Service, Wireless Cellular Network

***Abbreviations*—**Access Point (AP), Base Station (BS), Base Station Controller (BSC), Call Admission Control (CAC), Dynamic Channel Assignment (DCA), Fixed Channel Assignment (FCA), Mobile Host (MH), Mobile Switching Center (MSC), Quality of Service (QoS), Tier based Bandwidth Reservation (TBR)

I. Introduction

IN this competitive world, welcoming innovative thoughts and utilizing evergreen technologies for QoS provisioning in all aspects are very common. The wireless cellular network also comes under this concept. The cellular network [Nkambule et al., 2009] is dividing the geographical area into cells (theoretically hexagonal) each with a Base Station (BS) assigned, and with a number of radio channels assigned according to the transmission power capability and spectrum availability. A channel (which is commonly known resource) can be a frequency, a time slot or a code sequence. The cell sizes may vary from few meters to kilometres. Nearly, 7 to 11 cells make a cluster with different channel for each cell. Other clusters/cells can reuse the same channels with no two neighbouring cells having same frequency. Another concept called sectorization [Nkambule et al., 2009] was introduced so that each cell can be divided into 3 or 6 sectors with differing channels, due to which the frequency reuse is further enhanced.

The emerging technology deals with multiple classes of network traffic, which can be categorized as real time (voice and multimedia) and non-real time (mails, messages). Any Mobile Host (MH) residing in a cell can utilize the channel for communication with the BS. The BS is connected to the local Base Station Controller (BSC) [Kim & Varshney, 2002] and in turn communicates to the Mobile Switching Center (MSC) that is connected to the Public Switched Telephone Networks (PSTN) [Zahariadis & Kazakos, 2003].

When the MH initiates or receives a call, he may roam around the area covered by the network. If he moves from one cell to another, and the call has not yet finished, the network has to hand-off [Tripathi et al., 1998] the call from one cell to another at the cell boundary without the knowledge of hand-off and without much degradation of the service quality.

QoS provisioning in wireless networks [HSCTechnicalwiki site] is a challenging problem due to the scarcity of wireless resources, i.e. radio channels, and the mobility of hosts. Call Admission Control (CAC) [Ahmed, 2005; Ayman Elnaggar et al., 2008 and Missiroli et al., 2001] is a fundamental mechanism used for QoS provisioning in a network. It restricts the access to the network based on resource availability in order to prevent network congestion and service degradation for already supported MHs [Naghshineh & Schwartz, 1996; Ramjee et al., 1997]. A new call request is accepted if there are enough idle resources to meet the QoS requirements of the new call without violating the QoS for already accepted calls [Nuaymi et al., 2000]. Thus the wireless cellular networks deal with issues of resource reservation [Lu & Bharghavan, 1996; Nicopolitidis, et al., 2003], call admission control and user mobility in broader sense.

II. Resource Reservation Scheme

The Resource Reservation means to allocate appropriate radio resources for the new connections and the hand-off connections based on the availability in the current and neighbouring sectors (or cells) [Oliveira et al., 1998; U. Varshney & R. Jain, 2001].

2.1. Fixed Channel Allocation Scheme

Fixed Channel Allocation Scheme (static), which was proposed by Tripathi et al., (1998), also called Fixed Channel Assignment (FCA) uses non-sector concept and the bandwidth is permanently allocated for the new and hand-off connections within each cell. It ensures the availability of the resource for a connection and at the early days this scheme was broadly used. Fixed Channel scheme needs the frequency assignment to be manual and since it is less suited for Time Division Multiple Access (TDMA) and Frequency Division Multiple Access (FDMA) [Siva Ram Murthy & Manoj, 2008]. It might be vulnerable to co-channel interference due to the reuse of same channel. When the hand- off calls are becoming more, this method needs some more changes to cope with the situation. During minimum traffic the resources are wasted but at heavy traffic the scarcity of resource occurs. Thus this scheme makes the researchers to look for another improved method in providing QoS for the better communication.

2.2. Dynamic Channel Allocation Scheme

One of the improved schemes is the Dynamic Channel Allocation Scheme, also known as Dynamic Channel Assignment (DCA), which might have distributed Access Points (AP) in the cellular network. This is more suited scheme for TDMA and FDMA than the FCA scheme. DCA scheme avoids the frequency assignment to be manual and also provides better utilization of the radio resources.

Battiti et al., (2001) proposed a scheme, which is using non-sectors in cells, and the total available resources are distributed to all the cells. Any connection can take any one of the frequency channels that is currently available. Additionally, the frequency reuse is enhanced till the level of channel interference. Uniform frequency distribution is not followed in this scheme. This approach is quite better than the static approach since the amount of interference is minimum. But the problem is that there may be connection drops (especially, hand-off connections) in the heavy traffic areas and during busty traffic, [Kim & Varshney, 2002] since no additional radio resources are available.

2.3. Channel Borrowing Scheme

This scheme [Kim & Varshney, 2002] is an improved version of static scheme by Tripathi, where busy cells can borrow radio resources from their neighboring cells if available at the cell boundary. Frequency distribution is not uniform and so that the reuse is also enhanced until no co-channel interference has occurred. The main advantage of this scheme over the static scheme is that it reduces the hand-off call connection interference rate. While this scheme is dealt with sectoring concept, the interference rate is further reduced. But during heavy traffic, it behaves as the dynamic scheme, since it causes the calls to terminate due to bandwidth scarcity. So there is a further need for improving QoS in radio resource allocation.

2.4. Early Blocking Schemes

Early Blocking Scheme is mainly developed based on the hand-off prioritization approach. Diederich & Zitterbart (2005) this scheme with the aim of avoiding or reducing communication interruptions after hand-offs take place. The general concept of handoff prioritization schemes [Hong & Rappaport, 1999] based on early blocking is to reserve a certain amount of radio resources to be utilized only for hand-off connection requests. New call requests are not allowed to utilize these reserved hand-off resources. The early blocking scheme has two components to the legacy QoS provisioning: a hand-off resource reservation and an optional mobility prediction. Here the first component is responsible for calculating the hand-off resources necessary to support future hand-offs. To estimate future hand-offs is the main task of the mobility prediction. The mobility prediction can help find the right resource request, that is, those that would not lead to hand-off resource shortage in the future. This scheme extends admission control further to a distributed admission control. In this case, admission control also communicates with distant resource management instances of other cells, for example, neighbouring cells.

2.4.1. Taxonomy of Early Blocking Scheme

The following figure 1 shows the taxonomy of the Early Blocking Scheme. The dynamic class has got variety of schemes under it.

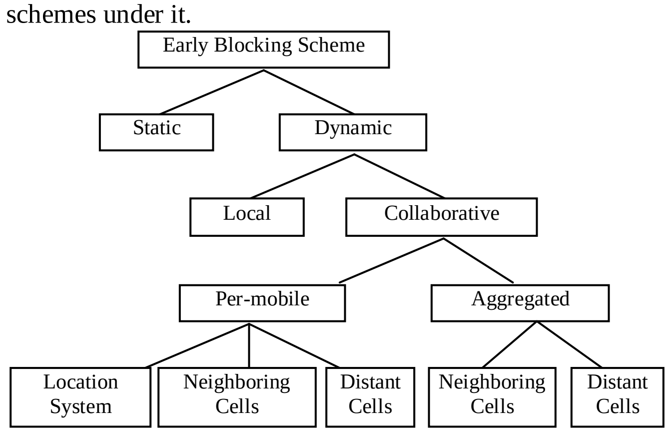

Figure 1 – Taxonomy of Early Blocking Scheme

2.4.2. Static and Dynamic Schemes

Static early blocking scheme are very simple. There is no mobility prediction component and no signalling among base stations to reserve handoff resources. Thus, static schemes are easy to configure. For some mobility scenarios, static schemes either lead to low resource utilization (if too many hand-off resources are reserved) or to hand-off resource shortages (if too few hand-off resources are reserved). Thus, they are less suited to be used in future mobile networks, in which the number of handoffs is expected to increase, in general.

In contrast, the hand-off resource reservation in dynamic schemes comprises an algorithm to determine the amount of hand-off resources automatically depending on the actual hand-off resource demand. In this manner these schemes can in principle adapt to time-varying mobility patterns, but they need a mobility prediction component to adapt the amount of hand-off resources dynamically.

2.4.3. Local Schemes

The main advantage of local early blocking schemes is that there is no signalling between base stations to retrieve data about possible future handoff events so that no per-mobile state information is kept in neighbouring cells to reserve resources for future handoffs. Thus, the complexity of local schemes is comparatively low (but higher than for static schemes). Furthermore, deployment of local schemes is quite easy as it can be started only in those cells of the mobile network where handoff drops actually occur.

2.4.4. Collaborative Per-Mobile Schemes

Basically, per-mobile schemes try to solve the following issues:

- Initiating a handoff resource reservation for a mobile terminal so that the necessary resources to support the handoff are available, when the handoff actually takes place.
- Deciding which neighbouring cell(s) to reserve the handoff resources and the amount of resources to reserve.

Per-mobile schemes potentially have a higher accuracy in determining the necessary handoff resources than local schemes or static schemes, for example, by using a location system. However, they may experience serious scalability problems in networks with many mobile terminals and a high number of handoffs. A general problem of schemes using a location system and a handoff zone is their limited applicability for mobile networks with small cells.

2.4.5. Collaborative Aggregated Schemes

In general, aggregated schemes provide a lower complexity than per-mobile schemes as they do not consider each mobile terminal individually, but instead use aggregated information to avoid per-mobile state information for reserving handoff resources and the associated signalling overhead. The drawback of using aggregation is, in theory, a tendency for a less precise handoff resource reservation, especially when comparing the aggregated schemes to per- mobile schemes using a location system.

The comparison of applicability of various early blocking schemes is given in the Figure 2. Thus the local schemes or aggregated collaborative schemes are identified as the most promising candidates for future mobile networks depending on the actual mobility pattern. There are still some unresolved problems in this area, a major one being that the existing approaches are difficult to compare to each other quantitatively. For the analytical approaches, it is important for a comparison that all build on the same set of assumptions, which should be as realistic as possible.

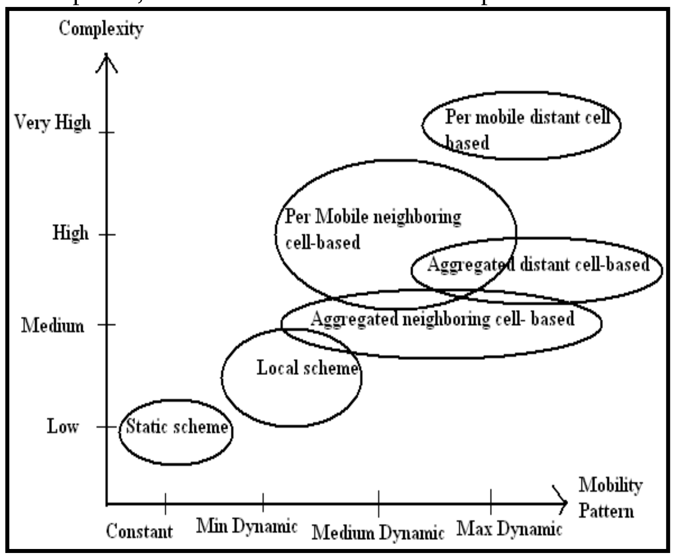

Figure 2 – Applicability of Different Early Blocking Schemes

2.5. Tier Based Bandwidth Reservation Scheme

One of the more suitable approaches, proposed by Wei Kuang Lai et al., (2008) for better QoS provisioning is the Tier Based Bandwidth Reservation (TBR) scheme in case of multimedia wireless networks [Chang Ho Choi et al., 2002]. The basic needs of this scheme are bandwidth scarceness and client mobility. Bandwidth scarceness is resolved by sectoring of cells, frequency reuse and power control. It says that the cells are divided into tri sectors with different frequencies in the neighbouring sectors. Due to this sectoring, the same frequency can be reused in the non-neighbouring sectors so that the capacity of the cells is increased. Next, the client mobility is resolved by admission control and resource reservation. These two concepts have been discussed earlier.

The next concept used in this scheme is tiering in sectored cellular network. The Base Station (BS) is equipped with tri- sectored directional antennas [Zahariadis & Kazakos, 2003]. The Mobile Host (MH) is tiered or simply 2-tiered: Tier 1 and Tier 2, according to its Pilot Signal Strength (PSS). If the PSS down below the predefined threshold, the MH is supposed to be in Tier 2; otherwise, it is in Tier 1. Each sector has four adjacent sectors where two of the four sectors are in the same cell and the other two sectors belong to the neighbouring cells.

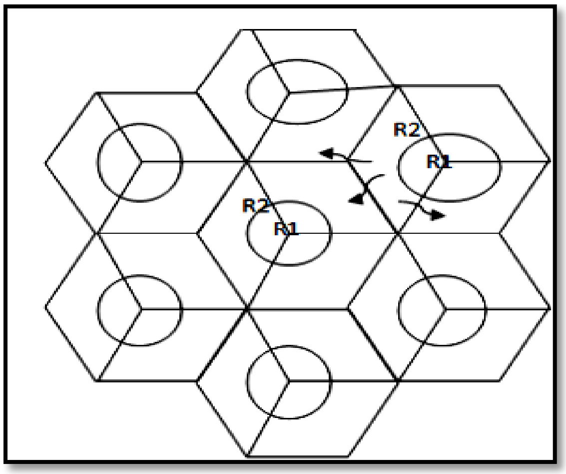

Figure 3 – Cells with Sectors and Tiers

- Cells with tri-sectors, - R1, R2 are tier 1 and tier 2 and Arrows- mobility of the host

In this scheme, it is essential for each BS to determine where the MHs reside. The schematic figure 3 shows the movement of the MHs. If they are in Tier 2 with the decreasing PSS, it implies that the MHs are moving away from the current sector. Now the hand-off probability increases, so the resource is reserved (that is, resource request is sent) only in two of the neighbouring sectors that are adjacent to the corresponding sector, instead of all its neighbouring cells. Additionally, the releasing of current reserved bandwidth is also required before hand-off to other cell/sector. Here the mobility prediction of the MHs is done based on the PSS value. Through mathematical analysis, the advantages of TBR scheme are proved and through simulation, it is compared with the other traditional schemes like no reservation, fixed reservation (static scheme) for proving its goodness.

Thus this scheme is better to avoid the wastage of bandwidth and to reserve necessary resource only in needed sectors. The only drawback that is noticed in this scheme is the mobility prediction may not be clear with PSS decreasing value.

Finally the enhancement of the TBR scheme, which includes the bandwidth-borrowing concept, is implemented and the results are compared. If a sector is not able to fulfil the need of a call request, the bandwidth can be borrowed from the neighbouring sector, where the enough amount of resource is available. This approach improves the TBR by reducing the call disconnections.

2.6. Comparison Results in terms of Traffic

A detailed comparison of all the schemes in terms of traffic intensity is given here. When the traffic is minimum and the mobility of the users is not much contemplated, all the resource reservation schemes are well suited. While the traffic increases, the FCA scheme performance decreases, DCA also is less suited. The other schemes are suited to this situation. During the heavy traffic, it could be found from the operational characteristics of the schemes that the hand-off prioritization and TBR are well-suited approaches for resource reservation. The following table-1 gives a clear suggestion about the performance of all the schemes under less, medium and heavy traffics.

Table 1 – Schemes Compared in terms of Traffic

Scheme	Minimum	Average	Maximum
Fixed Channel Allocation Scheme	Good	Performance degrades	Less Preferred
Dynamic Channel Allocation Scheme	Good	Better than fixed scheme	Less suited
Channel Borrowing Scheme	Good	Good	Performance degrades
Early Blocking Scheme	Good	Good	Good with local and aggregated scheme
Tiered Bandwidth Reservation Scheme	Good	Good	Good when compared to other schemes

2.7. Comparison Results for Resource Utilization

The resource reservation schemes discussed here can also be compared in terms of resource consumption, the time taken for each connection and relevant algorithms. The utilization is given in percentage after analyzing the distinctiveness of each scheme. The Early Blocking scheme is well suited for the micro cellular network. The TBR shows higher throughput than the other schemes. Each connection (new/ hand-off) should be given at right time, immediately after the request, which is performed by the TBR approach and the algorithm is also proved. The following table- 2 depicts the performance of all the schemes.

Table 2 – Schemes Compared in terms of Resource Utilization

Scheme	Resource Utilization	Time Taken	Algorithm
Fixed Channel Allocation Scheme	80% (from random comparison)	More for each connection	Proven
Dynamic Channel Allocation Scheme	73%	Dynamic	Proven
Channel Borrowing Scheme	73%	Lesser than fixed scheme	Not completely proven
Early Blocking Scheme	75% (suited only for micro cellular network)	Minimum	Not proved completely
Tiered Bandwidth Reservation Scheme	70%	Minimum	Proved with simulation and mathematical result

III. RESULTS

After the simulations, the TBR scheme, Dynamic scheme and the Enhanced TBR scheme performances are obtained in the form of graph. The remaining bandwidth is calculated in each

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approach and the values are taken over particular time periods. The remaining bandwidth after satisfying all the requests is more for the TBR approach than the dynamic approach. Under bandwidth borrowing scheme, other sector's resource is also utilized by the nodes, so the fulfilment of the requests is growing. So the remaining total bandwidth is less than the TBR approach. The following figure 4 shows the utilization of the bandwidth by the three approaches. The TBR approach conserves the bandwidth more than the other schemes.

Figure 4 – Bandwidth Utilization Graph

IV. Conclusion

In case of wireless cellular networks, providing an effective QoS for enhanced communication is a challenging task. The growing popularity of the 3G/4G networks has turned the attention of many researchers towards itself. While considering one of the QoS parameters, the resource reservation, there are many schemes with their own advantages and disadvantages. As the mobile users and hand-off rates grow, the need for the better QoS is also increasing. The earliest schemes basically good in less traffic, of course, they are not unsuitable. The Early Blocking and Tier Based Bandwidth Reservation Schemes play major roles in improving the bandwidth utilization. Even though various methods proposed regarding hand-off prioritization in case of Early Blocking Scheme, they are not compared quantitatively and they lag in real time scenario. But, they can be proved in real time and will be better schemes for QoS in wireless network. The next approach, the TBR Scheme seems to be more suitable for better bandwidth utilization and for better bandwidth conservation. The main advantage of this scheme is that it is proved mathematically along with the simulation results. Thus this scheme and the enhanced scheme with bandwidth borrowing can easily be adopted in real time usage and will provide a better QoS in the wireless cellular network. They have their own drawbacks but they are of less significance.

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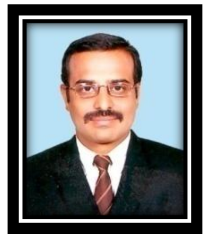

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