Efficient Bandwidth Allocation and Hand off Management in Radio over Fiber Systems

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Abstract

Radio over Fiber system provides high bandwidth up to 1Gbps to the wireless nodes using millimeter wave band technologies. The use of high frequency puts a limit on the size of the cell thus introducing the concept of Micro and Pico cells. The more number of cells in the network give rise to the increased number of hand offs. The challenges faced to such RoF systems are the efficient hand off with zero hand over dropping and the efficient allocation of bandwidth among the different base stations. RoF system architecture frees the base station from the processing overhead of MAC layer and shift it to a central controlling entity for base stations, called controlling station or Central station (CS). Our proposed solution gives the methodology for the efficient allocation of bandwidth to the base stations along with dynamic formation of Virtual Cellular Zones (VCZs) based on the bandwidth requirement in a cell area. We have devised a method for the dynamic allocation of bandwidth to the base stations and their addition and removal from the VCZs in order to provide more bandwidth to the user congested areas and minimizing the number of hand offs. The additions and modifications are suggested at CS and MAC layer for the hand off occurring between base stations controlled by two different CS.

I. Introduction

The demand for broadband access has grown steadily as users experience the convenience of high-speed response combined with always on connectivity. A broadband wireless access network (BWAN) is a cost-effective alternative to providing users with such broadband services since it requires much less infrastructure as compared to wired access networks. Wireless LAN based on IEEE 802.16e enables wireless communication systems to address mobile broadband services at vehicular speeds greater than 120 km/h with Quality of Service guaranteed comparable to broadband wired access alternatives. Intelligent transportation services are required for secure, smooth and reliable transportation. Along the road, Road Vehicle Communication (RVC) system is deployed to achieve high bandwidth and different quality of services for moving vehicles. One promising alternative to the issues are radio over fiber (ROF) based network since in this network, functionally simple and cost-effective BSs (in contrast to conventional wireless systems) are utilized. In particular, a large number of BSs, which will be deployed along the road and serve as remote antenna units for MHs, are interconnected with a control station (CS) that performs all central processing such as modulation/demodulation, routing, medium access control (MAC) and so on. This configuration leads to a centralized network architecture that could efficiently be used for resource management.

Since on motorway, greater the radius of coverage area is of no use due to the width of the motorway, [1] proposes effective and efficient mechanism of micro and Pico coverage cells. Since larger cells have large intersection area, so operating within a frequency found enough time to handoff between two adjacent cells. However, greater the overlapping area, higher would be the interference among the cells, so the cell sizes are kept smaller. Here is the issue of hand off time is much smaller as compared to hand off time required to be successfully switch if vehicle is moving very fast. [2] Proposes an efficient handoff mechanism in which it takes into account a central cell in which the mobile host resides and six adjacent cells. Whenever mobile host moves, the adjacent cell becomes the central cell and next cell becomes the neighbor cell. Radio over fiber (RoF) also supports very high bandwidths that were limited in traditional wireless LANs. So large number of mobiles hosts with varying quality of service demands are
supported. Due to this there could be congestion in some areas along the road and other areas could be sparsely populated. The demand is of efficient bandwidth management among mobile hosts.

The remaining part of this paper is organized as follows. The section II describes the handover management between different Base stations. Section III describes congestion control and bandwidth management strategy. Section IV discusses the analysis of section II and III and finally section V discusses the conclusion.

II. Design and Concept: Handoff Management

Mobility management is certainly a big issue in Road Vehicle Communication system. The system can support handoffs that could be fast or slow. Considering a vehicle that is on road with 60 km/hr and cell size is 50 meter then it will request handover after every three seconds. In addition the overlapping area between two regions is 10 meters so handover must be completed in 0.3 seconds. [3] ROF network at mm-wave bands for future RVC system based on CDMA has been proposed and implemented. To facilitate handover management all the BSs connected to a CS simulcast the same signal to communicate with MHs. A drawback of the system is that data cannot be properly received in the overlapping region between cells because of cochannel interference. [4] Utilizes TDMA/TDD and VCZs. Each VCZ composed of base stations of area of few tens of meter but operating at the same frequency. It resolves the problem of co channel interference among different base stations. Each CS has a super frame that have sub frame equal to the sub frames. Each BS has its frame according to the time slot. However this results in inefficient utilization of frequency spectrum in case if large number of base stations in a VCZ. [1] Proposes moving cell solution in which the MH considered in the central cell surrounded by six cells. The cell in which the MH moves becomes the central cell and creates new cells around it. This technique can only be applicable to telecom networks because it require user to occupy the channel frequency for the duration of session which can not be possible in a TDM system.

However, most of the work done so far is for inter-VCZ and intra-VCZ hand off. The problem exists if Mobile Host moves from one VCZ operated by a CS to other VCZ operated by a different CS. This results in connection drop sometimes. So there is always preference to smooth handoff between two VCZs that maintain ongoing connections with their quality of service and bandwidth requirements. So there is the need of efficient handoff and bandwidth allocation mechanism. [4] Discusses a technique of handoff between adjacent VCZs but it employs post-active strategy. When a MH enters a new VCZ, only then it start scanning for new frequency and request for bandwidth and if not found, drops the connection.

This section discusses the pro-active handoff among VCZs mechanism. It is assumed that MH is moving in one direction and the direction of MH is known to CS. It also assumes that bandwidth and frequency spectrum will always be available on the on-demand control station. The super frame information for a mobile host along with TDMA is utilized [4]. Fig.1 showing a MH moving from left to right and entering from second last BS to last BS.

![Fig 1: Inter CS hand off for a mobile host](image)

A CS is always synchronized to both of its adjacent CS. The information exchanged between the CS is the frequency channel being operated in the border VCZs. AS this communication involves latency of layer 3 as well, CS should always be updated in advance about the information of the adjacent CS. Since Control Station holds the information about MH, as the MH enters the last BS of the border VCZ, it is informed by the CS about the handoff occurring that involves another CS. CS gives MH the frequency on which the BS in the VCZ of neighboring CS is operating.

Mobile host in its free slots start scanning the new frequency and as soon as it comes in the overlapping region a request for handoff is placed to the new CS. This avoids the delay faced if the MH has to scan the full frequency spectrum in order to communicate with the next BS which may surely involve the connection drop.

Fig 1 shows a MH leaving cell n-1 and entering to cell number n. At this time the CS1 intimates the MH about the frequency of new BS. CSs are synchronized.
to each other by generating a VCZ-HF frame. This frame contains the information of the frequency channels operated in the border VCZ of the CS.

### III. Bandwidth Allocation

In RoF system architecture, different base stations controlled by a CS are divided into groups called VCZ. Each VCZ operates on different frequency where as the base stations in a VCZ operate on same frequency in TDM mode. A super frame comprising of sub frame for each base station is used for the communication with the Mobile nodes. [4] describes a MAC layer for the assignment of frames to the base stations and slot assignment to the mobile host within a single BS. The architecture works fine but there are few limitations in some scenarios. The bandwidth assignment is done with in a VCZ and every VCZ has its own carrier. There can be condition when two adjacent VCZ can have different user density where one VCZ would be fully occupied and require more bandwidth while the other VCZ would be having less number of users thus wasting a lot of slots. Thus fixed formation of VCZ results in poor performance in such kind of scenario.

We have catered this limitation by making the dynamic formation of VCZs with in a CS. VCZ are split and merged depending upon the bandwidth requirements of their corresponding users. The CS divides super frame into frames for each BS. This frame for BS contains the slots which are assigned to the Mobile hosts. There is time division multiplexing at two levels. First the base station has time duration of its frame assigned by the CS. At second level, each mobile host is assigned its time slot by the CS as the MAC level now spans from Mobile host to CS instead of Mobile host to base station. The slot assignment map filed in the frame of a BS contains the information regarding the slot assignment.

Let B_{total} is the total bandwidth available for a VCZ. B_{min} is the threshold of minimum bandwidth and B_{max} is the threshold of max bandwidth. CS has information about the bandwidth used within a VCZ as the slot assignment is done by CS. Whenever the bandwidth requirement of a VCZ goes below the B_{min}; both of its adjacent VCZ are checked for the bandwidth. The VCZ are merged if the accumulative bandwidth requirement of both the VCZ is lower than the B_{max}. In the other case, if the bandwidth requirement of a VCZ goes above the B_{max} then the VCZ is split and some part of it is merged with any adjacent VCZ such that the following equation is satisfied.

\[
B_{min} < B_a < B_{max}
\]

Here B_a is the actual bandwidth utilization or requirement of a VCZ. This equation should always be satisfied to keep the performance at optimal level.

Fig 2A shows the architecture of the network where VCZ1 is not having many users whereas VCZ2 is congested with the users. Fig-2B shows the system architecture after the formation of new VCZ takes place. Now there is almost equal load on both of the VCZ. However the effects of VCZ formation that result due to the change in the frequency of a BS when it moves from once VCZ to the other are to be considered and discussed in the future work. These effects are not discussed in this paper.

### IV. Discussion

The technique of handoff between controls stations employed is efficient because it takes into account the pro-active measures for frequency and channels allocation for mobile hosts. The handoff frame size is
set optimal to keep the backbone network less congested. Probing frame is used periodically after a short interval to make sure that the two adjacent CS are synchronized and keep the latest updated information of the frequency channel operated in the border VCZ of the neighbor CS. The bandwidth allocation is the critical part of the paper. The formation of VCZ affects a lot on the hand off requirement. If there are more VCZ formed there would be more hand off and if the number of VCZ is minimum then the zero drop hand off between BS can be achieved. The optimal values bandwidth threshold would be based on this tradeoff between bandwidth allocation and hand off requirement.

V. Future Direction

In future work we would be doing experimental simulation to prove the concept of our technique along with finding the optimal values of minimum and maximum bandwidth threshold. This would be very good analysis of trade of between the bandwidth allocation and hand off reduction in a RoF system. This would also give the concrete values for the interval over which one CS should be synchronized to its adjacent CS.

References