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Heterogeneous GPRS-WLAN Integration Based on Ad-Hoc Networks

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Abstract: In heterogeneous microcellular networks like 802.11(WLAN)-GPRS, users can roam around through vertical handoffs. The major problem in heterogeneous networks is that they support different QoS requirements and the users suffer sudden changes in data rates. This study proposes certain routing algorithms to extend the service time of mobile handsets in the wireless network with higher available data rate, thus improving the average available bandwidth.

Key words: Heterogeneous networks, WLAN, GPRS, routing

INTRODUCTION

In a heterogeneous architecture vertical handoffs let users have service from both GPRS and WLAN without any session termination and seemless to the end user. In international literature there are many researches trying to propose the merging of WLAN and GPRS networks into one heterogeneous interworking system. The loose coupling and tight coupling approach has been specified by ETSI[1-4] describing the architecture of operation. Pylarinos *et al*. [5] in described a possible WLAN-GPRS access network architectured based on 3GPP recommendations and a survey of the interworking in WLAN-GPRS Integration was given in[6]. Louvros[7] also described the high bandwidth user applications emerging from heterogeneous networks. The different supported rates in heterogeneous networks are still a big issue since users feel the degradation of service when they move away from WLAN Access Points (APs) and they are vertically handed over the GPRS network. The Ad-Hoc networks are a good common transport layer mechanism to extend the WLAN service time in a session call. Mobile handsets accommodate and deliver relay messages for other mobile handsets while there are mobile handsets available to form a path straight to the closest access point. And this is actually exactly what it is needed in a very dense city centre. In such a geographical area there are several overlay GPRS and underlay WLAN hot spots with minimum coverage and the idea is to keep the user serviced by the WLAN hotspots as more time as possible before he finally executes a vertical handover to the overlay GPRS cell. Of course the network topology and operability might be more complicated but the advantages we get are superior regarding the final QoS of the end user. First of all the mobile host can have higher transmission rate for longer time periods. Moreover a mobile handset, using the Ad-Hoc infrastructure extends the connection to the AP without need to change IP address.

THE NETWORK MODEL

In the general case a heterogeneous cellular network with ad-hoc connections will be composed of WLAN AP hotspots, ad-hoc WLAN supported relay handsets and GPRS Base Transceiver Stations (BTS). The cellular architecture will be composed of two different layers of a multilayer solution, as in Fig. 1. Originally in traditional heterogeneous network environment mobile handsets will prefer underlay WLAN APs with higher priority than overlay GPRS BTSs. Hence the first tuning will be on WLAN AP frequency band and if no WLAN AP is available, the mobile hosts will handover to the GPRS networks to

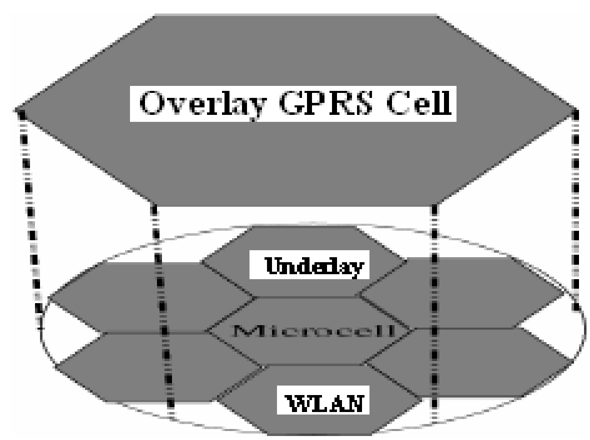

Fig. 1: The cellular multilayer architecture

keep the connection alive. In the proposed model however the mobile handsets, in case of no WLAN AP nearby, will have another alternative choice using ad-hoc WLAN relay handsets to reach a WLAN AP, before they end up to the GPRS network. The appropriate routing should use existing routing ad-hoc protocols. Such a protocol is the Destination Sequence Distance Vector (DSDV), discussed in[8], where every handset serves as a mobile relay host towards an existing AP. Its advantage is that it is simple and suitable for small size ad hoc networks as the microcellular networks in city centres. DSDV takes the least hop-counts as the shortest path. Every mobile host periodically broadcast routing information and update itself routing table. Once a relaying handset along the route leaves, re-routing should be launched quickly or the connection will be terminated. As the length of the route increases, the route broken probability will increases and the available connection will terminate resulting in a degradation of service. As a result the number of nodes in the ad-hoc connection (route length) is an important measure of network availability, used as an indicator to estimate the quality of an ad hoc route.

ROUTING ALGORITHMS

A problem however arises in case of multiroutes towards a certain AP. decision of best route might be a problem, since not only on the beginning should the handset decide about the best route but also on session time, due to many relay handsets move away from the route dynamically, the handset should reroute the connection towards the AP. A selection algorithm should be applied in order to keep alive the relay route in a dynamic environment. A simple one might be the selection of the route according to predefined number m of transit handsets towards the destination AP. According to this algorithm the handset will try to get (if not already connected) access directly to an AP. If there is no direct AP available, the handset will try to access a route with a number of relay handsets less than m. If more than one route exists then selects the one with the less relay handsets. Finally if there are no relay handsets then move to GPRS overlay. This is the Minimum Relay Connection (MRC) routing algorithm. This algorithm preserves the route length and hence the network availability. However it is time demanding since it requires the shortest path preserving the $\leq m$ criterion. Another algorithm might be the Any Route Connection (ARC) where the handset, whenever there is no direct AP and before moves to overlay GPRS, will try to find any available possible ad-hoc relay route connection. If there are more than one the first found will be used. This algorithm is faster than the MRC but it degrades the QoS due to its longer average route length.

SIMULATION RESULTS

In order to qualify the MRC and ARC algorithms based on DSDV protocol, the ns-2 simulation tool was used in a PC environment. For a city centre the typical overlay GPRS cell has a radius of 300-500 m and a WLAN hotspot 50-100 m. According to these ranges a city centre simulation area of 10000000 m^2 was initially considered with typical cell radius of 500 m for GPRS BTS cell and 100 m for WLAN AP cell. The area was supposed to be fully covered by 15 GPRS BTSs and mostly concentrated in the centre of the simulation area randomly situated 50 WLAN APs. Moreover a total number of 50 mobile handsets are supposed to move around the area according to a predefined move pattern related to streets and they are all supposed to have relay ad-hoc functionality. The total bandwidth (traffic load) that a handset can support in a point to point connection is supposed to be 1 Mbps and every session call is supposed to be 500 Kbps, resulting in maximum two supported calls per handset. Every AP can support up to 10 Mbps load and every session call was supposed to last for 5 min in average. Finally for the MRC we considered m = 5. Figure 2 shows the average number of relay handsets per overall system traffic load (in Mbps). The MRC algorithm is bounded up to 5 relay connections and the behaviour of the curve is nonlinear. This is because at low traffic load most of the sessions are in direct AP connections, except a few that are

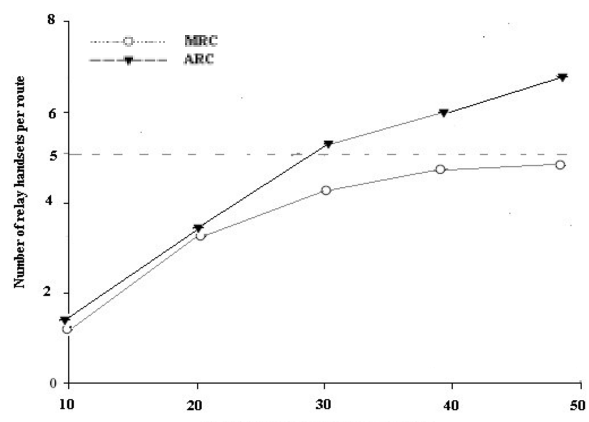

Fig. 2: Number of relay handsets per route versus the overall traffic load, MRC algorithm and ARC algorithm

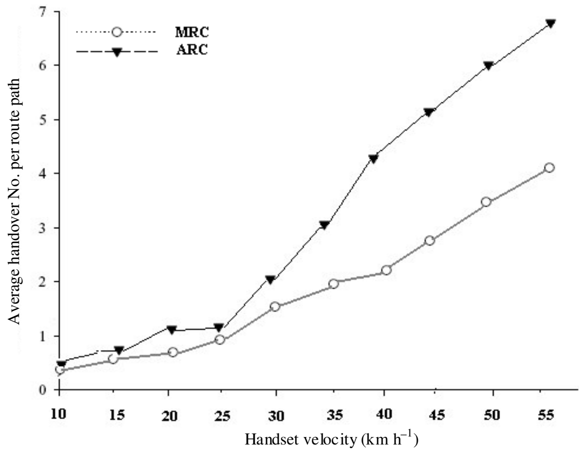

Fig. 3: Average Handover number against handset velocity, MRC algorithm and ARC algorithm

moving outside the centre and the average number of relay connections is almost one. As the traffic load is increased the bandwidth boundaries of AP and handset system forces the route path to increase and in high load the curve tends to 5. On the other hand the ARC algorithm is more linear since it randomly selects the route path without any constraint. In high load it diverts from the MRC as it was expected from the MRC constraint of 5 relay nodes. In Figure 3 the number of handovers per route path is plotted against the handset velocity, for a steady traffic load of 30 Mbps. It is obvious that for low speed handsets both algorithms have the same behaviour since from Figure 1 the average number of relay handsets per route path is almost equal. For high speed handsets however the difference is increased at almost twice. This behaviour demonstrates the advantage of MRC versus ARC algorithm since the more the handover numbers the more the probability of forced termination of a session.

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