Central Controller Handover Procedure for ETSI-BRAN HiperLAN/2 Ad Hoc Networks and Clustering with Quality of Service Guarantees

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***Abstract* – The European Telecommunications Standardisation Institute (ETSI) has almost completed standardisation of the *HiperLAN/2* (HL/2) system.**

In this paper the HL/2 "Central Controller Handover" procedure is presented, which is on the basis of the ad hoc networking concept of the HL/2 "Home Environment Extension". Beside a detailed description of the procedure, a performance analysis is carried out to evaluate the influence of the procedure on the packet delay. It is shown how the CC Handover enables dynamic clustering of centralised ad hoc networks.

I. INTRODUCTION TO HIPERLAN/2

On physical layer HiperLAN/2 (HL/2) provides a data rate of up to 54 Mbit/s resulting in a user data rate of up to 45 Mbit/s. Orthogonal Frequency Division Multiplexing (OFDM) is used with 52 sub-carriers, out of which 48 are used for data transmission. Adaptive modulation and adaptive coding can be applied to cope with varying propagation conditions and Quality of Service (QoS) requirements. For this purpose different "PHY-Modes" are defined. A PHY-Mode consists of a combination of a modulation and coding scheme. Possible modulation schemes are BPSK, QPSK, 16 QAM and 64 QAM. For the encoding a punctured convolutional code is used which can produce code rates of ¾ or 9/16. The system operates in the 5 GHz band and has a transmission range of up to 200 m depending on the applied PHY-Mode and propagation conditions.

Transmission is connection-oriented. Connections are set up by Radio Link Control (RLC) procedures. The Medium Access Control (MAC) is organised by a central unit, called Central Controller (CC). In the so-called HL/2 "Home Environment Extension" (HEE), which is an extension of the basic transmission protocols, an ad hoc network based on HL/2 has been developed. In the HEE the CC functionality is dynamically taken over by one of the terminals of a cluster. There is only one CC per cluster.

The CC is responsible for building MAC frames with a constant length of 2 ms, i.e. 500 OFDM symbols. Inside a frame a dynamic Time Division Multiple Access (TDMA) structure with Time Division Duplex (TDD) is applied. Two types of slots exist: short slots, which are 9 bytes long and can carry 52 bits of (signalling) payload, and long slots, which are 54 bytes long and carry 48 bytes of payload.

At the beginning of each frame the CC grants resources to the terminals by assigning the use of the slots in the frame to the different terminals. The terminals use the short slots to transmit resource requests for the following frame.

The ad hoc networking concept of the HEE is realised by two functions: "CC Selection" and "CC Handover". The CC Selection process provides an initial network set-up by choosing appropriate terminals to take over the CC functionality. Like the CC Selection, the CC Handover has been developed by the authors and is described in section II. of this paper. It is on the basis of a dynamic clustering of the entire network, which will be treated in section III.

II. CENTRAL CONTROLLER HANDOVER

Re-clustering of the network will become necessary during operation of the network. Reasons for re-clustering may be:

- switch-off of a current CC,
- power constraints of a CC,
- bad connectivity of one or multiple terminals,
- capacity constraints in one or several clusters,
- movement of the terminals, etc.

(Re-)clustering is achieved by means of the CC Handover procedure.

As the CC is responsible for association of the terminals, connection call control, radio resource management and scheduling, all relevant information about terminals and connections has to be stored inside the CC. This information, that we will call *RLC data*, has to be transferred during a CC Handover. The usual data transfer of the terminals goes on in parallel to the CC Handover signalling, i.e. direct link connections between terminals are maintained during and after the CC Handover.

The CC chooses a CC-candidate based on the clustering rule and sends a request to this terminal. Upon a positive reply of the CC-candidate all terminals are informed about the forthcoming CC Handover and all RLC procedures are stopped. Before the CC Handover itself is carried out, the higher layers are informed to be able to prepare for it.

The transfer of *RLC data* from the current CC to the CC-candidate starts after a positive response from the higher layers. A “Go-back-n” ARQ mechanism is applied to ensure the integrity of the *RLC data*. After successful transmission of the *RLC data*, the old CC indicates to the CC-candidate a point in time when to take over frame generation. This guarantees a seamless presence of the MAC frame.

Beside the *RLC data*, the CC-candidate also needs information about the *resource requests* of the terminals. Alternative strategies to get this further information may be applied by the new CC. As a reference scenario we assume that the information on resource requests was already available at the new CC.

To approach this situation as close as possible a CC-candidate could build its own database by *listening* to resource requests of terminals transmitted in the frames before a CC Handover.

An alternative solution could be that the CC-candidate does not store any information about resource requests before the CC Handover, but that it *polls* all terminals by granting them the use of a short slot in the first frame after CC Handover to transmit their resource requests and eventually a long slot for immediate data transmission (if capacity is available).

Both *listening* and *polling* solution cause an additive delay due to the discontinuity in the MAC scheduling process. The resulting Cumulative Distribution Function (CDF) of the additive delay in the first 10 frames after CC Handover compared to an ideal solution with no delay is shown in Fig. 1 for a Packet Error Rate (PER) of 0 % and a PER of 10 %.

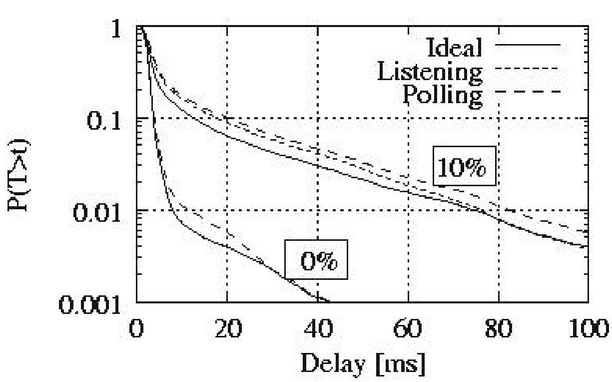

Fig. 1: CDF of additive delay with PER 0 % and 10 %

It can be depicted from Fig. 1 that both solutions cause an additional delay. This additive delay is higher in case of a higher PER. It is obvious that with an error-free channel the *listening* solution of the CC-candidate causes no delay at all, because the CC-candidate takes exactly the same decisions the old CC would have taken. The *polling* solution always causes a slightly higher delay than the *listening* solution of the CC-candidate due to the short slot overhead for the transmission of resource requests. Because of the low complexity of the *polling* solution it is nevertheless an interesting alternative.

III. DYNAMIC CLUSTERING BY CC HANDOVER

In this analysis it is considered that the number and location of clusters depends not only on the topology of the network, but also on the maximum allowed traffic per cluster.

In Fig. 2 two new clustering rules are compared against a well-known counterpart which is the *Lowest ID* (LID) algorithm. The LID foresees that always the device with the lowest ID becomes CC. We have called the two other algorithms the *Lowest Distance Value* (LDV) and the *Highest In-Cluster Traffic* (ICT).

The LDV foresees that each terminal calculates the sum of all distances to its direct neighbours divided by the number of the direct neighbours. The terminal with the lowest value becomes the first CC. All direct neighbours join this cluster starting with the nearest ones (as long as capacity is available).

The idea of the ICT is to build clusters based on the traffic of each terminal with its direct neighbours, to minimise the forwarding traffic. The terminal with the highest direct neighbour traffic is selected as CC. All direct neighbours of this terminal join the cluster (as long as capacity is available).

In our simulation the devices move with a fixed speed and a uniformly distributed direction interval (0 , 2*Pi). In Fig. 2 the resulting average number of CC Handovers per time is shown depending on the velocity of the terminals.

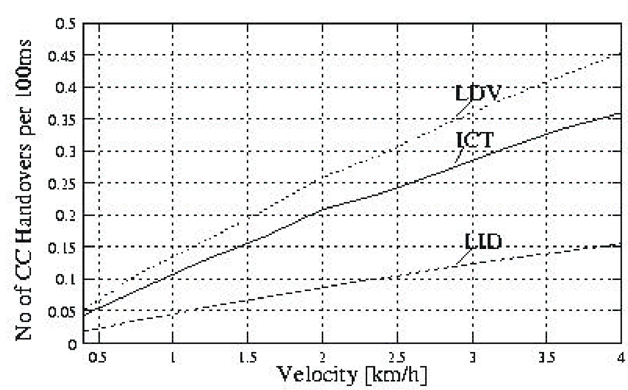

Fig. 2: Number of CC Handovers over velocity

As expected the LID algorithm gives the most stable configurations, but it has to be considered, that the LID does not take into account any capacity restrictions and that the traffic inside the clusters may exceed the maximal capacity. The LID therefore only serves as a lower bound for the number of CC Handovers per time. Out of the two algorithms considering the traffic, the ICT is the most stable one.