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INTER-VEHICLES COMMUNICATION: A NEW FRONTIER OF ADHOC NETWORKING

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ABSTRACT

Inter Vehicle Communication (IVC) has became a major topic during the last few years. Within the CarTALK 2000 project [1] a novel mobile ad Hoc Network, classified as fast moving outdoor network, will be developed. Main characteristics of such a kind of network are the large and variable number of mobile terminals, an extremely dynamic network topology and stringent requirements related to broadcast warning messages. In order to satisfy the basic requirements of such a radio interface, the framework of the UMTS Terrestrial Radio Access Time Division Duplex (UTRA-TDD) with modifications has been adopted as target system in the CarTALK 2000 project.

This paper introduces the architectural reference model of the communication system, discusses the main technical issues that arise when passing from a centralised network architecture (as the current UTRA-TDD communication system architecture) to a totally decentralised Ad Hoc mode [2]. In particular the introduction of a new, flexible and realible MAC architecture is investigated. Network throughput performance obtained by simulations are also discussed.

1 INTRODUCTION

Car traffic is one of the most prominent features of modern civilisation. In average we spend a considerable time of our daily life in cars commuting from home to work. With increasing traffic density on highways and inside the cities, the traffic situations become more and more complex for today's drivers. One of the most important objectives set by the European Commission is the reduction of 50% in road accidents within 2010, by promoting an **integrated safety**, including:

- accidents prevention through a dynamic management of traffic and environmental information;
- introduction of innovative preventive safety sytems for driver assistance;
- passive safety;
- emergency management;
- equipment of road infrastructures with innovative communication systems towards vehicles and service centres.

Within this approach, the development of intra and inter vehicles communications for Intelligent Transport System (ITS) has attracted major attention during the last few years. Typical applications range from emergency notifications in case of accidents, the distribution of Decentralized Floating Car Data for a Self-Organizing Traffic Information System [3], to more advanced applications like co-operative driving. For these applications, time and safety requirements cannot be fulfilled by existing air interfaces relying on a cellular network structure (e.g. GSM). Furthermore, by using ad hoc wireless communication, typical established Internet applications like web browsing, e-mail or chat applications can be provided without being bound to a costly cellular wireless network infrastructure [4].

To reach integrated safety the CarTALK 2000 project aims at the development of new driver assistance systems, which are based upon inter-vehicle communication. For this purpose, a mobile wireless Ad Hoc network that supports the requirements of the targeted co-operative driver assistance applications has to be developed and specified.

This paper presents the fundamental technology, the protocols and the architectural concepts proposed for advanced driver assistance systems. The proposed concepts represent a significant and valuable conceptual base to start the process leading to a future standardised communication system.

1.1 CarTALK 2000 application clusters

The main technological challenge consists in designing a mobile Ad Hoc communication system tailored to the demands and the requirements of various driver assistance applications. In particular three different CarTALK 2000 application clusters have been defined:

1) Information and Warning Functions (IWF): this kind of signals transmit information regarding stopped vehicles, traffic incidents (see Figure 1), detected traffic density, congestion, or road surface conditions allowing an early warning for the vehicles following on the same road. The transmission of short, aperiodic, broadcast, with high priority and low latency messages is required for the IWF service. To guarantee a fast warning in a larger zone the one-hop transmission range should be up to 1000 meters, but (through) multihop transmissions it should be possible to cover a wider area.

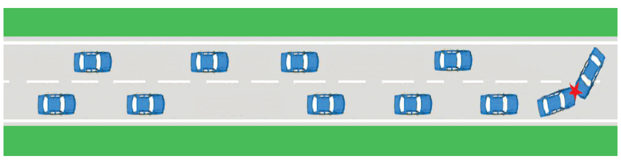

Figure 1: IWF - Basic Warning scenario example

2) Communication-Based Longitudinal Control (CBLC): this application can allow anticipating an early braking manoeuvre when an invisible vehicle in front is braking (see Figure 2). Tipical scenarious are: stop and go traffic, advanced distance keeping (anticipated driving, early braking) and advanced flow control and throughput. Medium sized messages have to be transmitted for the CBLC service. It requires normal priority in short periodic intervals. The one-hop transmission range should be up to 500 meters and multihop forwarding is desirable.

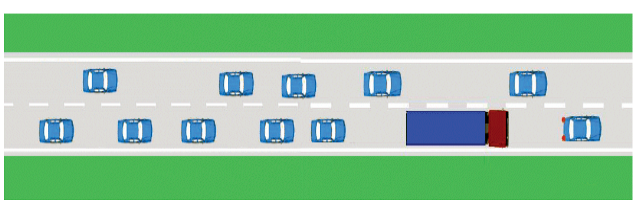

Figure 2: CBLC example: Early Braking

3) Co-operative Driver Assistance (CODA): this application can be typically helpful in highway entry (see Figure 3), merging scenarios, overtaking and lane changing and intersection assistance. A direct addressing of neighbouring vehicles and a reliable unicast communication link, with low latency, are needed for CODA applications. Information may be only sent upon request as for instance initiated by a vehicle on the ramp. The transmission range should be up to 500 meters and medium-sized messages are exchanged in a short interval, as long as the merging manoeuvre lasts. Broadcast functionality might be useful for the CODA functions as well, e.g. to send a gap request to all nearby vehicles. The CODA functions will use different type of messages, which can be easily separated in emergency, assistance and information messages of different priorities.

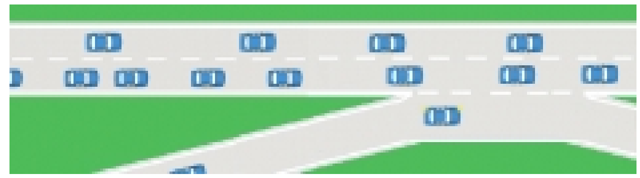

Figure 3: CODA example: Basic Merging

The philosophy of the CarTALK 2000 communication system is to modify an existing air-interface to minimise costs and to benefit from mass market. Requirements best suited to support the demands of the target system and applications are:

- High velocity (< 500 Km/h);
- Large radio range (>500 m);
- Adaptive data rate (30 kbps-1 Mbps);
- Availability of unlicensed spectrum;

On the other hand, services to be provided include:

- Multicasting of periodic data traffic to propagate cruising information to the surrounding vehicles for traffic control;
- Broadcast of alarm messages with different priorities;
- Point-to-point communication between terminals with QoS features;

Finally, due to the fact that terminals are installed in cars, no power consumption limitation (energy-saving) exist.

2 CARTALK 2000 PROTOCOL ARCHITECTURE

The simplified protocol architecture of CarTALK 2000 communication system, derived from the OSI model, is illustrated in Figure 4.

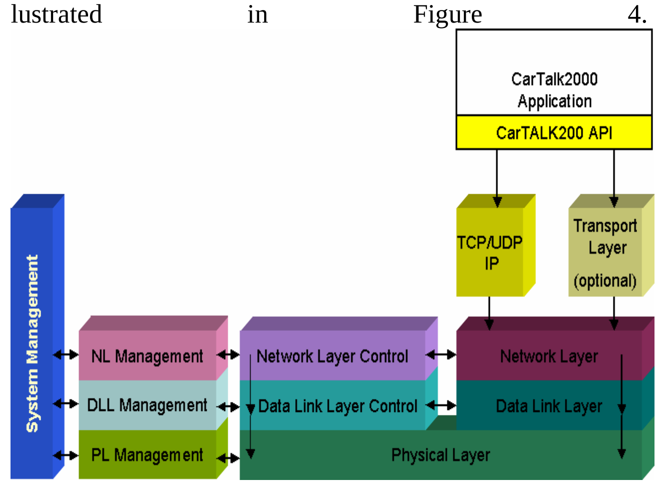

Figure 4: Protocol Architecture of the CarTALK communication system

The radio interface is functionally split into three layers: the **CT Physical Layer (PHY)**, the **CT Data Link Layer** (DLL) and the **CT Network Layer** (NL).

The **CT Transport Layer** is optional and we can consider it like an adaptation layer. It will be inserted only if required by applications. It is also possible that the applications, especially urgent messages, can communicate directly with the network layer, without this block in between. The TCP/UDP layers guarantee the compatibility with already existing standards and applications based on the Internet protocol.

The **CT Application Layer** describes an interface that can be used by advanced driver assistance applications.

In this paper we give some details on the air interface and focus on the MAC layer implementation issues.

3 CARTALK 2000 AIR INTERFACE

3.1 *Radio tecnology selected*

The physical layer should support high velocities, operation in multipath environments and high transmission coverage. The higher layers should support adaptation to different data rates and reservation of radio resources for high priority services. We have to standardise the air-interface (well-specified interfaces) and the system requires a licence-free frequency band. The choice of the communication technology plays an essential role in the project. Current solutions discussed in the scientific community do not take into account the highly dynamic topology of networks consisting of running cars. In the following a summary about the most interesting technologies, the selection of the best technology for our system and some technical and regulatory issues, are presented.

About the use of IEEE 802.11b in CarTALK 2000 communication system, we have to take into account its physical layer limitations. In particular, this technology does not support the required large communication distance of at least 1 Km, it is not able to meet the required performance in terms of packet losses in urban scenario and it is not guaranteed to operation at high velocities up to 500 Km/h [5]. Also strong limitations at MAC level have to be taken into account.

So with respect to the communication requirements expected, the communication technology for the target system, that we have chosen, is UTRA-TDD. In particular the low chip rate option (1.28 Mcps) called UTRA-TDD-LCR has been adopted, since an earlier market introduction can be foreseen. The UTRA-TDD-LCR proposal coming from the CWTS (Chinese Wireless Telecommunication Standardisation) has been admitted between the 3GPP systems starting from the Release 4 of 3GPP specification. A brief summary of the ITU standardisation process outcome in terms of accepted radio interfaces is given in the following Figure 5.

UMTS

Standard	TD-SCDMA	UTRA-TDD	UTRA-FDD	CDMA2000	UWCC136	DECT
Freq. band	*unpaired*	*unpaired*	*paired*	*paired*	*paired*	*unpaired*
IMT-2000	**IMT-TD** ***One mode of IMT-2000 CDMA TDD (⇨UTRA-TDD)***	**IMT-TD** ***Other mode of IMT-2000 CDMA TDD (⇨TD-SCDMA)***	**IMT-DS** ***IMT-2000 CDMA DS (direct spread)***	**IMT-MC** ***IMT-2000 CDMA MC (multi carrier)***	**IMT-SC** ***IMT-2000 TDMA SC (single carrier)***	**IMT-FT** ***IMT-2000 FDMA/TDMA***
Core network compatibility	*GSM MAP*	*GSM MAP*	*GSM MAP*	*ANSI-41*	*ANSI-41*	*ISDN*
Primary standardisation bodies	**CWTS 3GPP**	**3GPP**	**3GPP**	**3GPP2**	**TIA (US)**	**ETSI**

TDD

Figure 5: ITU - 2000 standardised systems

One argument for using UTRA-TDD in the CarTALK 2000 communication target system is the availability of the UMTS frequency range of 2010 to 2020 MHz, which is allocated as a license-free band for UTRA-TDD mode. Looking at the evolution of UMTS, it is furthermore expected that low cost components will be available. In addition, UTRA-TDD offers high flexibility with respect to asymmetric data flows and it is extremely well-suited for packet data transfer and for tomorrow's IP traffic. Finally it supports high speed mobility, sufficient user bit rates and quality of service (QoS). It is appropriate for operation in an Ad Hoc network and it allows communication over large distances and operation in a multipath environment.

3.2 UTRA-TDD basics

The Universal Mobile Telecommunications System (UMTS), the 3rd generation of mobile radio systems, defines two different duplexing schemes for the radio access: Frequency Division Duplex (FDD), also referred to as UMTS Terrestrial Radio Access (UTRA)-FDD, and Time Division Duplex (TDD), referred to as UTRA TDD, which has two options: high chip rate (3.84 Mchip/s) and low chip rates (1.28 Mchip/s).

For UTRA-FDD the use of Wideband Code Division Multiple Access (WCDMA), i.e. a pure CDMA based technology, is recommended, whereas for UTRA TDD a hybrid Time Division and Code Division Multiple Access (TD-CDMA)scheme is used. TD-CDMA is very well suited for TDD operation due to its inherent time division component.

In order to allow for the development of low cost terminals that support FDD/TDD dual mode operation, the fundamental system parameters such as chip rate, bandwidth, and modulation scheme of both access technologies are equal. In Table 1 the basic system parameters for UTRA FDD and TDD are summarized.

	UTRA FDD	UTRA TDD HCR	UTRA TDD LCR
Access Technique	DS-CDMA	DS-CDMA + TDMA	DS-CDMA + TDMA
Chip rate	3.84 Mcps		1.28 Mcps
Carrier spacing	5 MHz		1.6 MHz
Frame duration	10 ms		10ms (2x5ms subframe)
n. of slots per frame	15		Sub frame: 7 normal TSs + 3 special TSs
Modulation	DL: QPSK UL: Dual channel QPSK	QPSK both UL and DL	QPSK both UL and DL 8 PSK optional

Table 1: UMTS FDD/TDD basic system parameters

Due to the exclusive and fixed assignment of the used bandwidth to uplink and downlink, the UTRA FDD is less suited to be adapted to a decentralized access scheme allowing for the direct communication between two arbitrary stations within radio range. By contrast, UTRA TDD, that offers a much more flexible assignment of the radio resources, it is very well suited for the adaptation to an ad hoc mode.

4 AD-HOC MAC: A NEW MAC ARCHITECTURE

4.1 MAC basic issues

The design of a MAC for vehicle-to-vehicle communications considered by CarTALK 2000 is a challenging task mainly because it must support broadcast services in an efficient and reliable way. Many applications, such as the transmissions of alarms and cruise information, require that all terminals are able to quickly access the channel and to safely transmit packets to neighboring terminals or even to all terminals in the network [8]. Since the applications have different quality and bandwidth requirement, the MAC must be also able to support service differentiation.

Due to the ad-hoc environment, the MAC operates on a physical channel that, unlike Ethernet, does not present broadcast characteristics and transmissions of terminals in different broadcast segments can potentially collide on other receiving terminals (the hidden-terminal problem). Approaches such as the CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance), adopted in the Distributed Coordination Function of IEEE 802.11 [9], do not completely solve the problem even for point-to-point transmissions (see [10] for a comprehensive review of protocols proposed to avoid the hidden-terminal problem in point-to-point communications). For the broadcast service (single-hop broadcast) the hidden-terminal problem is completely unsolved and transmissions are unreliable since only the physical carrier sense is adopted and no acknowledgement is provided by receiving terminals. Furthermore, no centralized algorithm, such as the Point Coordination Function of IEEE 802.11, can be applied, making very difficult to provide services with QoS requirements, such as voice traffic.

Providing a broadcast service over the whole ad-hoc network (multi-hop broadcast) is even more challenging problem. Most of the advanced broadcast protocols, such as the tree-based protocol in [11] do not work well for ad hoc networks due to the dynamic nature of the network topology. Hence, the flooding approach and its variants, have been proposed as the preferred means to propagate routing and broadcast service [12]. In flooding, each station that receives a broadcast packet retransmits it just once until all terminals are reached. Such a procedure is highly inefficient in networks that present an high degree of connectivity. In fact, in networks with n terminals flooding requires n transmissions of the same information, while a single transmission is sufficient to reach all terminals in fully connected networks. In addition, since the multi-hop broadcast service is provided at the network layer exploiting a MAC layer based on random access, flooding suffers from the broadcast storm problem [13]. In fact, neighbouring nodes are likely to re-transmit a broadcast packet almost at the same time, causing massive collisions.

For the application scenario considered by CarTalk 2000, we have proposed ADHOC-MAC, a new MAC architecture that is able to overcome the drawbacks listed above proving a reliable single-hop and multi-hop broadcast service [14]. ADHOC-MAC is based on the Reliable R-ALOHA protocol (RR-ALOHA) [15], which is a completely distributed access technique capable of dynamically establish a reliable single-hop broadcast channel on a slotted/framed structure for each active terminal on the net. This channel is used to provide:

- prompt and reliable layer two connectivity information on all the stations of the network;
- contentionless access to a reliable single-hop broadcast service;
- prompt means to reserve additional bandwidth and QoS as the applications require, in a completely distributed way;
- an efficient multi-hop broadcast service;
- efficient point-to-point communications that exploit parallel transmissions.

Here we review the RR-ALOHA mechanisms and the multi-hop broadcast service which are fundamental for the application scenarios of CarTalk 2000.

4.2 RR-ALOHA

To present the operation of ADHOC-MAC protocol we describe the network topology grouping terminals into clusters: each terminal of a cluster is directly connected to all the others of the same cluster, while terminals of different clusters cannot directly communicate at the physical layer. Such a cluster is defined as One-Hop (OH). Considering the graph describing the ad-hoc network, OH-clusters are maximum-cardinality sub-graphs where all nodes are connected to all the others (clique). Of course, terminals can belong to more than one OH-cluster, leading to the case of non disjoint clusters. The union of OH-clusters having a common subset is called a Two-Hop (TH) cluster.

The access mechanism of ADHOC-MAC can be classified as Dynamic TDMA where channels are assigned to the terminals according to terminal needs. However, Dynamic TDMA still needs a protocol to coordinate inter-terminal transmissions. One protocol capable of achieving dynamic channel sharing is the well known Reservation ALOHA (R-ALOHA). In R-ALOHA, "trial and error" transmission is used to access an available slot, e.g., slot *k* in a frame of *N* slots. If the transmission is recognized as successful the slot is reserved for that terminal in subsequent frames, and is no longer able to be accessed by other terminals until the channel is released. The correct operation of R-ALOHA requires a central repeater through which the terminals receive all the transmitted signals and, most importantly, obtain the same slot status information, e.g., busy, free, or collided.

To implement a Dynamic TDMA in ad-hoc networks we devised a new protocol, the Reliable R-ALOHA (RR-ALOHA) protocol, that allows the same R-ALOHA procedure to be applied to the ad-hoc environment by requiring that each terminal periodically transmits in the OH-cluster the information, called the Frame Information (FI), on the status of previous slots. Each active terminal that wants transmitting and receiving packets in a reliable way, needs to acquire a channel, i.e. a slot in the frame of N slots, called basic channel (BCH). This channel, acquired using the access procedure defined by RR-ALOHA, can be correctly received by all the terminals within the same OH-cluster and is used to transmit FI, other signalling information, and also payload information.

The FI is a vector with *N* entries specifying the status of each of the preceding *N* slots, as observed by the terminal itself. The slot status is BUSY if a packet has been correctly received or transmitted by the station, otherwise it is FREE. In the case of a BUSY slot the FI also contains a short identifier of the transmitting terminal. Based on received FIs, each terminal marks each slot *k* as RESERVED if slot *(k-N)* is coded as BUSY in at least one FI received in the slots from *(k-N)* to *(k-1)*, or as AVAILABLE otherwise. Figure 6 reports an example of FIs transmitted by terminals of a TH-cluster.

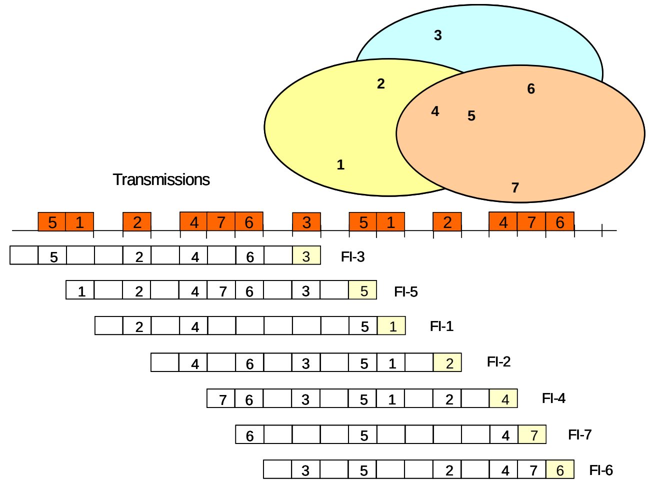

Figure 6: FIs transmitted in a TH-cluster

As in R-ALOHA an available slot can be used for new access attempts. Upon accessing an AVAILBLE slot, terminal *j* will determine after *N* slots that its attempt is successful if the slot is coded as "BUSY by station *j*" in all the received FIs; otherwise the transmission has failed.
Note that the terminals belonging to the same OH-cluster see the same status (AVAILABLE or RESERVED) for all slots, terminals belonging to different OH-cluster of the same TH-cluster mark as RESERVED all the slots used in the TH-cluster, while terminals belonging to disjoint OH-clusters can see a different channel status. As a result, slots can be reused in the network.

The access procedure above assures the correct operation of the RR-ALOHA protocol [14]. Slots acquired with RR-ALOHA procedure (BCHs or additional slots) can be used for single-hop broadcast. Active terminals can also use the BCH to piggyback the requests for additional slots, which can be managed in a distributed way according to service priorities.

4.3 Multi-hop Broadcast

The ADHOC-MAC operation can be extended to a broadcast service over the whole network. This is referred to as the multi-hop broadcast service, since in the ad-hoc network environment some terminals are required to relay the broadcast packets to enable them to reach all the terminals. The relaying function in ad-hoc networks is usually implemented at the network layer, but the connectivity information provided by the FI allows to efficiently provide the multi-hop broadcast service at the MAC layer. Note that even the routing protocols at the network layer can exploit this service to maintain updated routing table or to discover path on-demand.

As with flooding, the broadcast packets in the ADHOC-MAC network need to be numbered, and the relaying procedure is applied only once, the first time the broadcast packet is received by a terminal. Let C_i be the set of neighbours of terminal *i*, i.e. all the terminals in the same OH-cluster, and C_j, for any $j \in C_i$, the sets of neighbours of *I* neighbours. Given that terminal *i* receives a broadcast packet from terminal *z* in slot *k*, we define the set of neighbours that have not received the packet in slot *k* by $S_i \subseteq C_j$,. All these sets are identified by terminal *i* through the information carried by the FIs received in the *N* slots following slot *k*.

At slot (*k+N*), terminal *i* recognizes whether or not it needs to relay the broadcast packets. Terminal *i* does not relay the packet if S_i =0 or if, for at least one $j \in (C_j, - S_i)$ the following condition is satisfied:

$$S_i \subseteq C_j \ \text{AND} \left\{ |C_j| > |C_i| \ \text{OR} \ \left\{ |C_j| = |C_i| \ \text{AND} \ ID_j > ID_i \right\} \right\}$$

where ID_i denotes the address of terminal *i*. Basically, terminal *i* does not relay the packet if its set S_i is a subset of C_j, and if either C_j, has higher cardinality than C_i or, having the same cardinality, the address of *j* is higher than the address of *i*. According to this procedure only selected terminals will relay the broadcast packets, thus significantly reducing the number of retransmissions with respect to flooding. Even if the optimality of this procedure is not guaranteed in the general case, it is worthwhile noting that, in most cases, the minimum set of relaying terminals needed to cover the whole network is selected [14]. In the example of Figure 6 if terminal 1 transmits a multi-hop broadcast packet, only terminal 5 will relay the packet to the other terminals according to the above procedure.

5 ONE HOP BROADCAST PERFORMANCE

We developed an object-oriented simulator written in C++ in order to test the proposed ADHOC-MAC. Our tool reproduces a square topological area with parametric dimensions. In order to avoid the border effects we use a wrap around approach according to which the simulated area is like lying on a torus surface. The mobile terminals enter the system according to a Poisson random process whose intensity, λ_a , is fixed throughout each experiment.

The position of each incoming user is chosen randomly on the square surface and is not changed throughout the simulation, since no mobility module is implemented at this stage. Each terminal hangs in the system for a period of time which is exponentially distributed and during this time it generates packets according to a Poisson arrival process with intensity λ{packets/s}. A terminal exits the system as soon as its lifetime is over.

As far as the propagation model is concerned, we assume that the received power depends on the path loss only, i.e. on the distance between source and destination. In the results presented in the next subsection neither fading nor shadowing are taken into account, so the connectivity among terminals is completely determined by the distance from one to another. Each active terminal transmits at fixed power level, which is the same among all the terminals, so the propagation model is completely described by a transmission range radius R_{tx}, which is a parameter of the simulator.

The physical channel is assumed to be ideal, i.e. no errors due to multipath and fading holes are taken into account. Therefore, errors may occur due to collisions of contemporary transmissions only.

In the following, the results are obtained considering a square area with edges 1 Km long. The average life time of each terminal is equal to 300 frames and each frame is composed of 30 transmitting slots.

To obtain steady state results the simulations have been run for 900 seconds. The first 100 seconds are used as warm--up time, and the corresponding statistical results are neglected. The remaining 800 seconds are divided into 4 simulation runs. During each run the results are collected and used to calculate one sample of each statistical quantity used for the evaluation. The output results have been tested according to the t-student statistical test. For all the measures reported in the following (S, G, etc) the confidence interval is under the 5%, for a 95% confidence level.

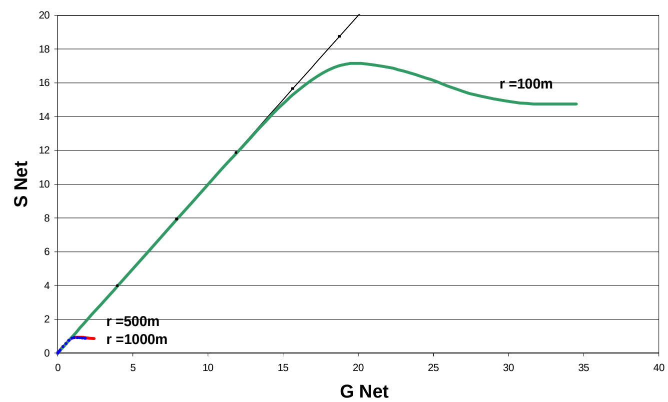

Figure 7: Network Throughput (S) vs Network Traffic (G)

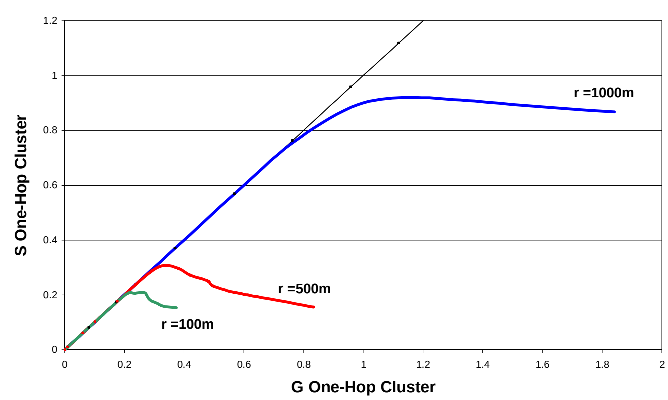

Figure 8: One Hop Cluster Throughput (S) versus One Hop Cluster Traffic (G)

Figure 7 reports the network throughput (S), defined as the total number of successful transmissions per slot, versus the network traffic (G), defined as the overall number of transmissions per slot, including the colliding ones. Three different curves are plotted in the figure for different transmission ranges (r=100m, 500m, 1000m).
From the plotted curves, we observe that the cases with transmission range equal to 1000m and 500m show the same capacity. In the case of transmission range equal to 1000m, all the region is covered by a single cluster, i.e. all the mobile terminals are within the transmission range: no parallel transmissions in the same slot are allowed and the number of transmissions per slot saturates at the value of 1. If we assume r equal to 500m, the simulated domain is completely covered by two non disjoint clusters. However, since we are considering a single hop broadcast transmission, also in this case no parallel communications between the two clusters are allowed and the capacity of this configuration saturates to 1.

If the transmission range is reduced, and consequently the number of clusters within the domain gets larger than two, the number of parallel communications increases, i.e. the same broadcast channel can be contemporary used in disjoint clusters, allowing a higher S. In the case of r=100m, ADHOC MAC allows up to 17 successful broadcast transmissions per slot.

Figure 8 reports the same S/G graph of figure 7 when the traffic statistics are collected on each single hop cluster. A single hop cluster is defined as the set of terminals that can be reached by a single hop broadcast transmission of any other terminal in the cluster. In other words, while figure 7 gives an idea on the reuse efficiency of ADHOC MAC, figure 8 stresses the effect of the neighboring clusters on the capacity of a single cluster. If r=1000m all the slots in the frame can be shared by the users of the single cluster, so the capacity gets close to 1, since all the slots in the cluster can be used by terminals belonging to the cluster itself. The fact that, in practice, S saturates to 0.92 is due to the collision during the access phase. When r decreases, the capacity of the single hop cluster decreases since the number of non disjoint clusters in the network increases and consequently some slot in each frame of each cluster cannot be used for transmissions, because already taken by transmissions of a neighboring cluster. As an example, when r is equal to 100m only 20% of the slots in each frame of each cluster can be used for broadcast transmission within the cluster. The remaining 80% is used by the neighbor clusters.

Finally, figure 9 shows the average delay (in term of frames), in the acquisition of the basic channel versus the throughput of the single hop cluster (S). The average delay remains around 1.5 frame until the capacity is reached. This means that when the system operates far from the capacity the acquisition of a basic channel takes 1.5 frames on average. When the capacity is reached almost all the available slots are used for ongoing transmissions, the collisions in the access procedure grows and the access delay grows consequently.

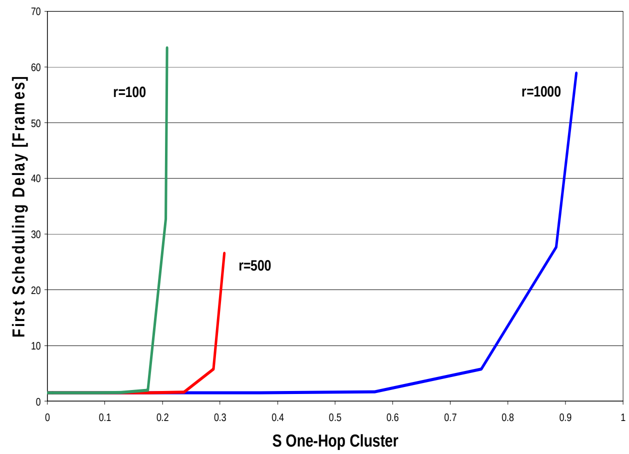

Figure 9: Access Delay versus One Hop Cluster Throughput

6 CONCLUSIONS

This paper describes the architectural reference model and the main tasks involved in the development of inter-vehicles communication system based on UTRA-TDD, in the framework of the CarTALK 2000. The project aims to contribute to the **Integrated safety,** as defined by the European Community**,** designing a mobile Ad Hoc communication system tailored mainly to the demands and requirements of three driver assistance applications: Information and Warning Functions (IWF), Communication-Based Longitudinal Control (CBLC) and Co-operative Driver Assistance (CODA).
The highly dynamic changing topology and the lack of a centralised reference, characteristics of the Ad-Hoc mode, pose some relevant challenges in using the UTRA-TDD communication standard. In particular Synchronisation, Power Control, MAC and RRM procedure have to be revised. To solve the open problems and to exploit the suitability of the TDMA, we presented an entirely new MAC protocol for ad hoc networks, which is able to deal with the hidden terminal problem and to overcome most of the problems that have been recognized in existing MAC architectures. It is based on a framed structure in which a broadcast signaling channel is set up in a completely distributed way by the RR-ALOHA protocol, also part of ADHOC-MAC.

The performance obtained by simulation and presented in the paper show the reuse efficiency of ADHOC MAC and outlight the effect of the neighbor clusters on the capacity of a single cluster. With small cluster radio most of the slots in a frame are used by the stations in neighbor clusters. The average delay for the acquisition of the basic channel versus the throughput of the single hop cluster is very small until the capacity is reached and shows the effectiveness of the protocol in a fast changing network environment.

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