A Case for Using MBMS in Geographical Networking

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Abstract— **Mobile communications are spreading at a fast pace, from telephony to vertical applications such as healthcare, transportation or energy. In the case of transportation, their target is usually a limited geographical area. Geographical networking is currently under study, with proposals for identifying the target area by adding a geographical enhancement to the IP protocol. In this paper, we propose to complete this kind of solution by defining some cross-layer cooperation and an abstraction framework where networking and link layers contribute to improve the efficiency of the geographical coverage and enable this feature in all types of multimode terminals, either ITS (Intelligent Transport Systems) vehicle stations or user personal handheld devices. This system is best suited for applications involving the broadcast of periodic messages, for example when a short-term event has to be covered. It is described using the MBMS (Multicast/Broadcast Multimedia Service) and the multicast/broadcast functional entities standardised by the 3GPP for the cellular networks, but it is generic enough to be applied to other types of access networks under some conditions.**

Keywords -- GeoNetworking, Heterogeneous Networks, Multimode Terminals, MBMS, LTE, Cross-Layer Design, Vehicular Networks, Multimedia Broadcasting.

I. MOTIVATION

The miniaturization of electronic components and the rapid expansion of mobile communications have brought Internet in most of the handheld devices. New vertical applications are being designed to improve our lives with added security and flexibility. The future mobile devices will bring to people smart healthcare, living, transportation and energy. In the transportation domain, a whole set of technologies and applications is being designed for Intelligent Transport Systems (ITS) to enhance the quality of our travelling experience. Many use cases have been described where various types of requirements and communications intend to provide additional security and road safety, traffic efficiency or daily life simplification. Several cases are expected to distribute regular notifications to the ITS stations by transmitting periodic permanent or temporary messages broadcasted from an infrastructure centre. These messages contain for example road warnings to inform the driver of a potential hazard, contextual speed limit information or regulations, information about road modifications due to changes in the traffic flow or just entertainment and practical information for the user. The current standardization bodies [1][2] envision to have these applications deployed together with an adapted version of the IEEE 802.11 access technology; but other technologies such as the cellular network broadcasting, could be used as well in these cases, because they are already deployed, have a larger coverage area and enable the usage of standard personal handheld terminals. As another trend, the future mobile terminals become multimode. They contain more than one radio interface and are able to access different types of networks according to the context. It will then be possible, from the information provider point of view, to choose the most convenient network to transport the messages.

One of the requirements of the ITS applications is the capability to broadcast information in a limited geographical area. The solutions that are currently designed focus mostly on adapting the networking layer and the IP protocol stack, while using the standard link layer derived from the IEEE 802.11. However, the geographical topology of IP routers is usually not very well known, thus requiring broadcasting the data in areas much larger than what is really needed. This implies some useless filtering in an important number of Mobile Terminals (MTs) which are actually out of the target geographical area, because the access network is used transparently. On the contrary, it is possible, when deploying an access network, to map its topology to geographical coordinates. This is already done in some networks with localization functionalities and could help reduce the processing requirements from the MTs.

In this paper, we propose an enhanced system to extend this solution by developing a cross-layer cooperation and abstraction framework, combining the adaptation of the IPv6 protocol and the associated geo-networking entity with the localization capabilities of the Layer 2. This system is divided into two parts. In the network, the transmission endpoints compute an initial selection of the necessary radio cells to reduce geographically the coverage area, only based on the information provided by the networking layer. In the mobile, the protocol stack is enhanced to drop at Layer 2 level the reception of the out-of-scope data, thus alleviating the workload of the networking layer. This case is applied to the cellular technology which provides wider coverage areas, built-in control and broadcasting with the MBMS

(Multicast/Broadcast Multimedia Service) and geographical capabilities thanks to the comprehensive topology knowledge of its network deployment.

This paper is organized as follows. Section 2 provides some background on multimode terminals and the Media Independent Handover (MIH) services, the MBMS functionality for cellular networks and on geographical networking. The proposed system is described in section 3, first through some cross-layer cooperation at network level, then with the introduction of an abstraction layer and a geo-networking control entity in the mobile. This description is followed by a review of the benefits of the new solution. In section 4, this system is applied to some example use cases and the conclusion is drawn in section 5.

II. RELATED WORKS

A. Multimode Terminals

The trend in the mobile technologies nowadays is the conception of multimode devices, with an increasing number of interfaces. Building and operating such devices can become very complex if each access technology has to be addressed directly and separately by the networking entities. Following this trend, the IEEE, through its 802.21 working group, has developed a standard to allow a mobile terminal to seamlessly roam across different types of 802.x network access technologies. Named Media Independent Handover Services [3], this standard allows in addition the integration of cellular networks. It is designed to facilitate mobility related operations by providing a standardized, technology-independent interface just below the OSI network layer and above the technology-dependent data link and physical layers. In order to help upper layer protocols, the 802.21 defines three different Media Independent Services which offer the generic triggers, information and tools needed to perform handovers. The Event Service provides the data needed to manage the event classification, filtering, triggering and the reporting of dynamic changes in the different links. The Command Service allows the mobility management entities to control the different link behaviours. The Information Service is responsible of distributing technology-independent, topology related information to the mobile terminals in order to allow them to perform a handover with the maximum of information available. This standard is currently further developed to support an extended set of services, such as security or QoS, and technologies, such as broadcasting technologies. It is particularly suited to control the operation of the upcoming multimode terminals.

B. MBMS

The MBMS is an enhancement of the UMTS (Universal Mobile Terrestrial Service) system [4] which provides a point-to-multipoint capability for Broadcast and Multicast Services, allowing resources to be shared in the network. Inside the MBMS sub-system, the Bearer Services take care of the operation of the radio link between the Radio Access Network (RAN) and the Mobile Terminal, and of the capability to deliver multicast datagrams to multiple receivers, thus minimizing the network and radio resource usage. Figure 1 shows the 3GPP reference architecture for MBMS [5]. Compared to the unicast model, this architecture introduces a new functional entity, the BM-SC (Broadcast/Multicast Service Centre) which consists of five sub-functions: membership, session and transmission, proxy and transport for signalling, service announcement and security. The MBMS functionality enables a smart usage of radio-network and core-network resources, with an emphasis on the radio interface efficiency. Using Multicast packets can be forwarded from one source to many receivers without overloading the network and consuming the scarce radio resources.

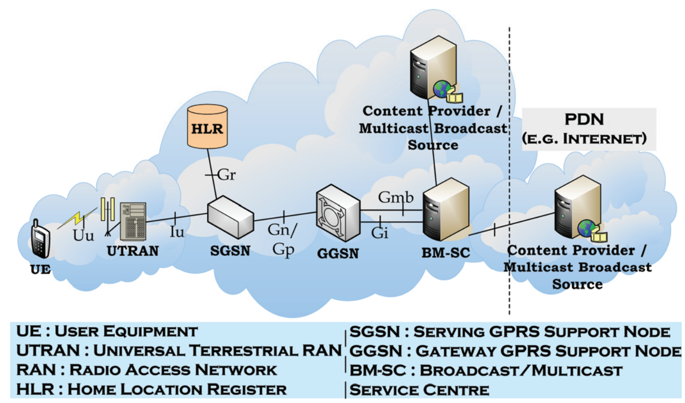

Figure 1. 3GPP Reference Architecture for MBMS

However, the deployment of this technology has been limited due to its performance level in terms of bit rate and the interference introduced by the broadcast channels on the regular radio channels. As the LTE (Long Term Evolution) of the cellular systems is enhancing the capacity and efficiency of the RAN, the MBMS is evolving and adapted to benefit from these improvements. One of the key features for this evolution is the introduction of the MBMS-GW (MBMS Gateway) in the architecture between the BM-SC and the E-UTRAN (Evolved UTRAN), and the mandatory usage of IP multicast in the User Plane between the MBMS-GW and E-UTRANs for both multi-cell and single cell transmission. The MBMS-GW allocates the IP multicast address to be used by the downstream nodes. Source Specific Multicast has been selected, with the MBMS-GW operating as the actual head of the multicast distribution tree.

C. Geographical networking

Geographical networking is the delivery of network-layer packets to nodes within a limited geographical region [6]. Several options can be chosen to achieve this objective. One option is to include a geographical locator in the terminal IP address [7] and use this information to route the packets towards their destination. But it introduces many security problems, among which a lack of privacy, as described in [8][9]. Another option is to route the packets towards a pre-defined area larger that the target region and have the receiver associate the destination information with GPS (Global Positioning System) coordinates to determine if it belongs to the destination group. This second option protects the privacy, but on another hand, the target location information must be inserted in the IP header to avoid deep level processing in the router and additional transport delay. In IPv6, one can consider inserting this destination option in an extension header as in [10] or have the IP flow tunnelled in a geo-networking layer protocol, such as the C2C-CC Network Layer [2].

III. Enabling Geographical Broadcasting With MBMS

Geographical networking is intensively used in the emerging technologies for Intelligent Transport Systems. Different scenarios are defined, according to the communication endpoints (Vehicle -V- or Infrastructure -I-) and type (unicast or multicast). As it focuses mainly on introducing the MBMS, this study considers principally scenarios with infrastructure-to-vehicle (I2V) geographical broadcasting communications. As explained in Section I, there are many use cases where these scenarios are relevant.

Current studies for geographical broadcasting are focusing mostly on the networking layer [11][12] and implemented in the IP protocol by using specific multicast addresses attributed to geographical areas. The IP protocol is assisted by its mobility extensions and, eventually, by some networking sub-layer. We propose here to enhance this solution by introducing some cross-layer cooperation between the networking and link access layers. This cooperation is complemented by an abstraction framework for the access technologies which aims to increase its efficiency and extend its applicability.

A. Cross-Layer Cooperation

At the network layer, some geographical information is inserted in the packet together with the destination address to identify the target reception area. This information is usually defined by the basic coordinates (latitude, longitude, height) associated to a description of the area [13]. It can be included in an extension header similar to [10] or in the header of the associated networking sub-layer.

At the origin of the data flow, the source application provides the messages to the network layer which encapsulates them in broadcast packets. We suppose here that the UMTS/MBMS network has been selected as one of the technologies to transfer this information towards the target MTs. The packets enter the cellular network at the BM-SC (see section II.B). In the BM-SC, the Session and Transmission function is responsible to schedule the sessions and label each one with an identifier. In the new system, it is extended with geographical capabilities. When it receives a new flow of information, it searches in the IP header of the packets whether some geographical coordinates defining the target area have been inserted. It correlates this information with a database of the network topology, which is known from the cellular network deployment, and determines the refined set of base stations (or eNodeBs) located in that zone. It generates the necessary signalling [5] to trigger the participation of the downstream nodes to the multicast distribution tree independently of the receiving ITS stations which are highly mobile. It is during this "MBMS Session Start" procedure that the MBMS-GW requests the E-UTRAN to join the tree. When this is achieved, all the bearers are established and the users who are located in the destination area and who have activated the corresponding service are able to receive the desired information, when available, without the need to allocate any additional dedicated radio resource. Such cooperation between the access technology layers in the network nodes and the technology-agnostic networking layers can also be applied to any other type of access (e.g. IEEE 802.11), as long as some network entity in the transport path of the flow and located close to the access network is able to map the received geographical coordinates onto a well-known network topology and select a subset of access points for forwarding the packets.

B. Abstraction Framework

The future Mobile Terminals will be multimode terminals, enabling the dynamic selection of the access network according to various criteria such as the coverage area and signal quality, the available bandwidth or user preferences due to the subscription rates. In order to reach the maximum number of mobile users and terminals, including the personal handhelds, some traffic and safety applications will be more efficient if their data are transferred in more than one access network, allowing the usage of multiple technologies in parallel and the selection of the best and most convenient one. In these terminals, an abstraction framework such as the one proposed by the IEEE 802.21 [3], can be efficiently used to reduce the complexity of processing the technology specificities, and can even participate in the filtering of the target area.

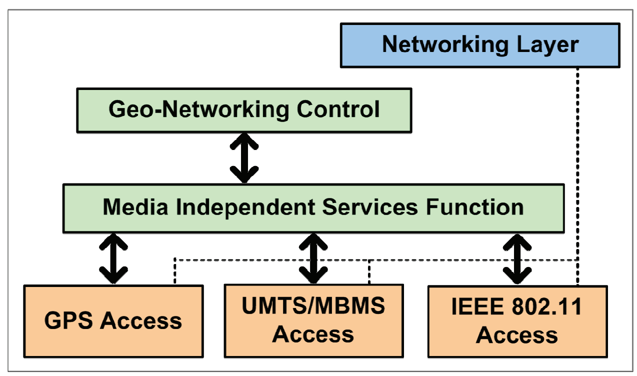

Figure 2. Abstraction Framework in the Mobile Terminal

The proposed abstraction framework is illustrated in Figure 2. As soon as the broadcast session has been completely started in the network, data packets are transmitted on the established bearers. When a MT, which has initiated the reception of the service, enters in the area, it starts receiving these packets through one or several of its active technologies. The initial packets received by each interface are forwarded by the abstraction or Media Independent framework towards a geo-networking control entity (GNC). The same framework is used to report the MT dynamic geographical coordinates to the GNC. These coordinates are most often provided by a GPS interface in the terminal, but can also be retrieved from the localization functionality of another technology, hence the benefits of using an abstraction layer. The GNC computes an initial correlation between the received coordinates and the target area information contained in the network header of the IP packet. If a match is found, the decision is taken to continue the reception of the broadcast session on the MBMS interface for instance. The flow can now be forwarded to the corresponding networking layer. If no match has been found, the decision is taken to filter out the broadcast session. A command is sent to the link access layer and the MBMS Bearer Service in the MT, which tunes off the technology for this flow and thus avoids a pointless filtering in the network layer. However, later on, a periodic re-evaluation of the correlation is performed with an updated input from the localization system, to take into account the MT mobility, potentially start the reception of the broadcast information and forward it towards the networking layer. The correlation is stopped when the flow of packets relative to this service dries up, either because the terminal has moved out of the broadcast area or because the traffic information itself is not relevant anymore, and the broadcasting has been stopped.

By using this process, the MBMS or Link Layer access cooperates with the networking layer to improve the whole system efficiency and enhance its capability.

C. Benefits of the new System

The cooperation between the network layer and the access layer, either in the network, in the mobile or both, enables a more precise and efficient delivery of the I2V broadcast information. When the MBMS is used, this system takes advantage of the comprehensive knowledge of the network topology by the UMTS Core Network and of its broadcasting services. It benefits from an already deployed infrastructure which can easily cover large or small areas, as needed, requiring only some limited modification of the BM-SC functional entity. The technology abstraction, built according to the MIH services, enables the efficient usage of multimode terminals with the best available access network at any time. In this case, an ITS application and service can easily be made accessible not only to the vehicle station, but also to any user personal handheld terminal, as long as it has been prepared to receive it by the introduction of an abstraction layer, such as the MIH Function, in its supported protocols.

IV. APPLICATION SCENARIO

As described in Section I, the type of application for this system may vary according to the type of access technology that is used. The MBMS is not really appropriate for critical safety applications where very short time delays are required, even though this has been highly improved by the LTE. V2V communications with specialized technologies are more adequate in that case. However, this solution can be used when periodic information has to be delivered using the roadside infrastructure, if it is available, or the MBMS in the transition period before the roads are fully equipped with the ITS specific supporting infrastructure, or even both as explained above. It works best in the case of temporary traffic efficiency applications. As an example, in the case of a crowded temporary event, such as a trade show, Olympic Games or a sport event, the up-to-date list of remaining parking slots can be transferred to the vehicles and their users, without having to invest in any additional equipment for the infrastructure or to overload the existing networks. In this case, the requirements are quite simple: a monitoring Control Point is established at the location of the event and transmits periodically updated information. A communication channel is configured to the UMTS network which targets the MBMS infrastructure and enables the reachability of the various terminals and vehicle stations.

Figure 3 illustrates another application scenario where some road information about a new highway has to be delivered to the vehicles. It shows the UMTS/MBMS network with its Core Network (including the BM-SC and the MBMS-GW) and two base stations, BS1 and BS2. Only one of the base stations, BS1, is located in the target geographical area, here the surroundings of a highway.

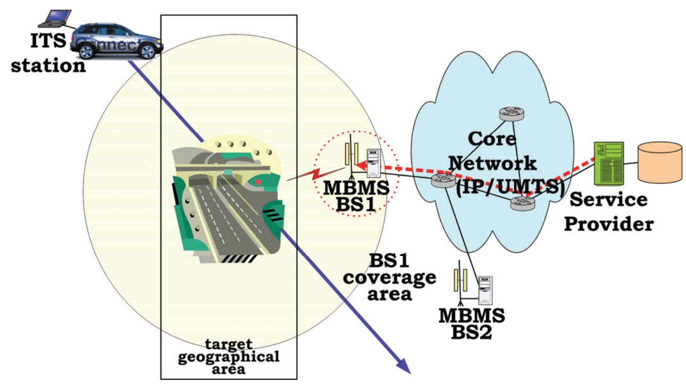

Figure 3. Example Application Scenario with MBMS

The car contains an ITS station, either directly from the vehicle or as the user personal handheld. During this example, it passes through the highway area. As it enters the BS1 coverage area, the terminal starts receiving the broadcast data from its MBMS access, but filters them out because it is not yet located by the highway. Later on, the car gets closer to the road, the correlation gives a positive decision, so the data flow is received and transferred to the networking layer for processing towards the application layer. It is filtered out again as the car leaves the BS1 coverage area. While the car goes through the BS2 coverage area, no more broadcast is received so the correlation processing is completely stopped in the terminal.

V. CONCLUSION

This paper presented some cross-layer cooperation for the design of the geographical broadcasting functionality in Intelligent Transport Systems. In addition, this system makes use of an access network abstraction to improve the efficiency and applicability of the proposed solution. It has been applied to the case of the MBMS functionality of UMTS networks, which is particularly suited for broadcasting information in a well-defined geographical area. In the coming years, the MBMS performance and capabilities will be improved by the new LTE standard of the 3GPP, extending the possibility of application scenarios for this system. The proposed solution requires only a limited modification of some network entity in the UMTS/MBMS network and the introduction of a new protocol layer in the mobile. It is totally compatible with the existing solutions that are being designed. This system will be developed and simulated during further research activities on ITS technologies improvement.

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