Multichannel Joint Rate and Admission Control Mechanism in Vehicular Area Networks

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***Abstract*—Vehicular area network (VAN) as a part of vehicular network is developed rapidly by integrating different techniques, e.g., sensing, wireless communications, GIS and satellite navigation techniques. The integration of these techniques forms a heterogeneous network and intimates strong requirements for the VAN gateway design. In this paper, a cognitive VAN gateway is designed to meet requirements of the heterogeneous network. The multichannel joint rate and admission control (MJRAC) with better quality of services (QoS) is proposed in multi-channel VAN scenarios based on the joint rate and admission control (JRAC) method. The simulation results show that MJRAC can increase the overall QoS greatly, especially for low-data-rate services.**

***Keywords*—cognitive gateway, QoS manager, MJRAC, multichannel**

I. Introduction

Since the idea that connecting objects by using RFIDs is initiated by Kevin Ashton in 1999, internet of things (IOT) has witnessed fast development of itself in many countries, such as US, Europe, China, South Korea, etc. IOT covers many subareas, e.g. home network, agriculture network, vehicular network, etc. [1] Among them, the vehicular network is one of the fastest developing areas all over the world. It aims to realize communications among cars, people and infrastructures by implementing sensors, sensing networks and the Internet. The huge amount of data traffic have be developed for managing such an intelligent network.

The vehicular network employs several different techniques, e.g. sensing, wireless communication and satellite navigation techniques [2]. Vehicular area network (VAN) [3] is a part of vehicular network, which is a wireless network based on communication devices in cars. VAN is made within a vehicle, and forms a small local area network (LAN) by connecting vehicular sensors. The vehicular gateway, the mobile management center and the wide area network (WAN) form its basic framework. Thereinto the vehicular gateway, which involves both the techniques of LAN and WAN, is the key part of VAN, and it connects cars with multimedia services. Sensors in a car is able to from one or several LANs. While the communication within a LAN can be realized by one of the technologies like ZigBee, bluetooth and IEEE 802.11p, the interconnection of those LANs has to be dependent on vehicular gateways. So in such a heterogenous network, a gateway that is able to connect various networks is required, and it should also handle the multimedia communications with a good QoS management. Therefore, the QoS management algorithm implemented in the gateway should have an excellent ability to ensure the quality of all kinds of services while managing the network, controlling network utilization and collecting network usage information.

In order to make heterogeneous networks connected better, data frameworks from different networks should be changed to a common one. In this case no matter what techniques are used in several sensing networks, data frameworks coming out can be transformed into a unified framework for further information exchange with other places. Such transformation ability should be realized by VAN gateways. As IEEE 802.11p covers network and transport layers of VAN ([4], [5]) but lacks specifications in upper layers (e.g. the application layer), there is a demand on the VAN gateway design with cross-layer functions.

Joint rate and admission control (JRAC) algorithm is proposed in [6] to improve the home M2M network. It works on both network and application layers with a single channel at a time. JRAC can maximize network utilization and keep service fairness as well as handling multimedia services in UPnP protocol, which is suitable for the VAN cognitive gateway.

Generally speaking, there are often more than one channel required for multiple service transmissions in vehicular networks [7], [8], and each channel contains serval service information. Hence, JRAC cannot handle such cases. In this paper, a multichannel joint rate and admission control (MJRAC) algorithm for the VAN cognitive gateway is proposed to handle multi-channel QoS promotion required in vehicular networks.

The rest of this paper is organized as follows: section II gives a brief introduction of vehicular area network (VAN) and gives a topology of VAN cognitive gateway; section III introduces the QoS promotion mechanism suitable for multichannel networks — MJRAC, then its simulation results are given and analyzed in section IV. At the end section V concludes the ideas of this article.

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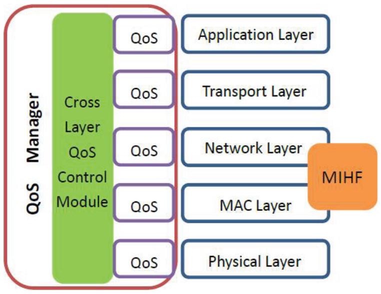

Fig. 1. VAN cognitive gateway architecture

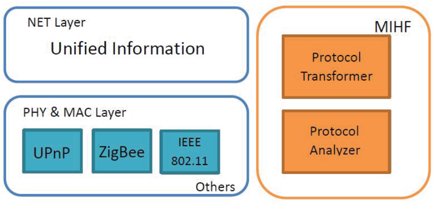

Fig. 2. MIHF implementation

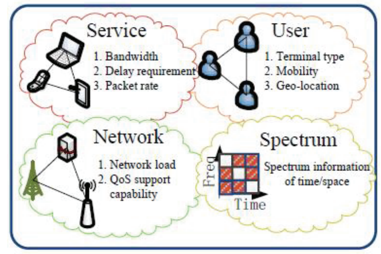

Fig. 3. Multi-domain cognition [13]

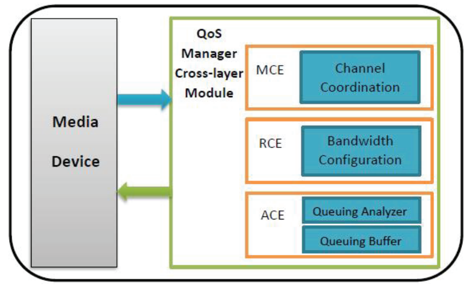

Fig. 4. MJRAC's machine model

II. Proposed Cognitive VAN Gateway Design

Considering VAN gateway requirements discussed in section I and IOT gateway designs in [9] and [10], a cognitive VAN gateway is proposed in Fig. 1. Since only gateway itself is considered in this paper, most specific features of the vehicular network (i.e. moving environment, varying vehicle density, etc. [11]) becomes insignificant, except for Doppler effects when handling receiving messages and multi-channel features when getting access to a network.

The PHY and MAC layers of the proposed cognitive VAN gateway can access different types of networks, e.g. UPnP network, IEEE 802.11p network, etc. In order to enable them to be connected without protocol difference, a media independent handover function (MIHF) [7] unit is used to unify their data frameworks in upper layers. It can contain protocol analyzer unit and protocol transformer unit, so that different data frameworks from heterogeneous networks can be analyzed and transformed into unified one, to better illustrate the concept of MIHF, in this paper the implementation is re-shown in Fig. 2.

There is one QoS manager that supports cross layer QoS management. It comprises five QoS control modules with each module being in charge of each layer, and a cross-layer QoS control module that is able to better control the gateway in a comprehensive scenario. With the cross-layer feature, QoS management algorithms that are capable of improving more than one layers can be more easily implemented and supported.

The cognition feature of the proposed gateway is illustrated in the QoS manager. Instead of spectrum cognition [8], [12], the multi-domain cognition studied in [13] is applied in the proposed gateway's QoS manager with a full scale cognition of spectrum, network, user and service as shown in Fig. 3. Hence, the proposed cognitive VAN gateway is able to collect those messages by requests, statistics, direct detection, etc.

The detection of multi-domain cognition is implemented in the QoS control module of each layer, then information in each layer can be collected at the cross-layer QoS control module for further use. Thus each layer's QoS control module can promote QoS of its layer by perceiving specific information, and the overall QoS can be promoted better in union under the help of comprehensive information.

III. QoS Improvement in the Proposed Cognitive VAN Gateways

MJRAC is a combination of JRAC with multi-channel coordination, and is able to promote the service access ability in multi-channel scenarios like VAN. It accesses more coming sessions while keeping fairness of multimedia services in service channels (SCH). In addition, MJRAC utilizes the feature of multi-channels and is implemented in the QoS manager in Fig. 1.

A. Machine Model

The machine model containing media device and QoS manager cross-layer module is shown in Fig. 4. The media device conveys multimedia resources and generates services that are sent to other places. The QoS manager cross-layer module comprises multi-channel control entity (MCE), rate control entity (RCE), and admission control entity (ACE). MCE is responsible for multi-channel coordination, including channel switching. RCE is responsible for bandwidth allocation. It configures current bandwidth of a channel and sends the message to ACE. ACE is a unit that decides whether a new piece of information can be added to the network based on queuing analysis. In addition, it has a queuing buffer that queues services when more than one session is required to access the network.

B. MJRAC Process

The process of the proposed MJRAC is shown in Fig. 5. The media device is initialized and sends requests to the QoS manager to ask for admission to the target network. When receiving this, the QoS manager starts the network cognition to obtain the necessary information (e.g. network congestion information, bandwidth needed, service priority, service scalability, etc.) of new service. If such messages cannot be provided, the admission request will be denied by the ACE.

After the necessary information is received, MCE and RCE are invoked to configure the bandwidth together. It aims to enhance the performance of all multimedia services as well as to maximize the utilization of all channels.

It has been assumed that there are totally T SCHs in the network. If there are $M_t - 1$ services in the t th SCH of the network, the new one becomes the M_t th session for the t th SCH. For a scalable service, there are N acceptable rates, so that the j th acceptable rate of the i th session in the t th SCH can be represented as $r_{i_t}^{j}$ $(1 \leq t \leq T; 1 \leq i_t \leq M_t; 1 \leq j \leq N)$. Let $\Phi_t(R)$ denote the whole set of possible configurations in the t th SCH, in which $R_t(r_1; r_2; ...r_M)$ refers to the rate configuration of that channel.

When a new session is to be admitted, MCE will initialize the bandwidth configuration. This process will start from the 1st SCH to the T th to look for enough space for accessing the new service. Once a channel with enough space is found, the new session will be configured to be added there with its largest optional rate $r_{M_t}^{N}$ (Note that if it is not scalable, then r_{M_1} is considered). That configuration result will be reported to ACE for the admission decision.

Upon receiving the initial configuration, ACE will start queuing analysis. If the configuration is not passed, MCE and RCE will be notified to reallocate the bandwidth jointly. In this case, MCE will be in charge of channel switching, and RCE will do the bandwidth allocation of that channel. When MCE switches to the 1st SCH, RCE will allocate the bandwidth of that channel starting from the second largest optional rate $r_{M_1}^{N-1}$ from the new session. (Note that it is for scalable services) By doing so, the affection to existed sessions can be minimized. Once a possible configuration $\Phi_1(R)$, where rate configuration is $R_1(r_1; r_2; ...r_M^N)$ or $R_1(r_1; r_2; ...r_M)$, is finished, RCE will send it to ACE. $\Phi_1(R)$ is used to access the new session if it itself passes the ACEs analysis. However, if $\Phi_1(R)$ is also denied by ACE, the option rate of the new session will be decreased once again, i.e. its rate will become $r_{M_1}^{N-2}$. So the new rate configuration $R_1(r_1; r_2; ...r_M^{N-2})$ is sent to ACE for admission decision. Such adjusting process of the new session iterates until $R_1(r_1; r_2; ...r_M^1)$ is denied.

For non-scalable and scalable services that cannot be admitted to the network even with their lowest option rate $r_{M_t}^1$, RCE will reallocate the spectrum of current sessions. The scalable session with the largest rate will be adjusted first. This configuration will be also decided by ACE. Such reconfiguration of the first channel usually ends up with $R_1(r_1^1; r_2^1; ...r_M^1)$. If it is also denied by ACE, i.e. the first channel cannot access the new session, MCE will switch to the 2nd channel for a reconfiguration. Similar configuration process will iterates until $R(r_1; r_2; ...r_M^{N-2})$ in all SCHs cannot pass ACEs analysis. If that is the case, then the new session cannot go into the network and it has to wait.

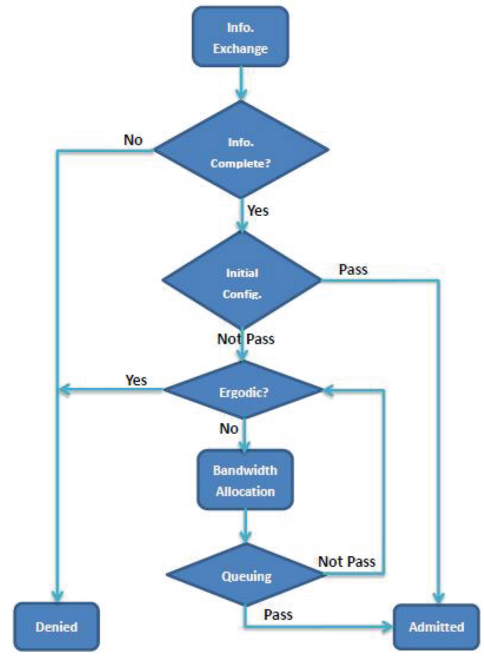

Fig. 5. MJRAC operating process

TABLE I
SIMULATION PARAMETERS

	Audio	Video	Data
Data Rate(kbps)	840-2840	3700-4700	1200-3900
Service Durations(s)	90-50	60-20	12-6
Priority	3	2	0

IV. Simulation Results and Analysis

In the simulation two cases are simulated and compared: one is a normal access using CSMA multi-channel coordination, and another one is a promoted access scenario where MJRAC is implemented. The parameters for the MJRAC in the simulation are listed in TABLE I. We set one type of service to have three option rates, so each type of service has three different bandwidth requirement and three duration values. WLAN environment is considered in the simulation. There are six service channels and one control channel, and MJRAC is implemented in service channels.

It is assumed in the simulation that the total bandwidth of network is 60MHz (each SCH is 10MHz) and the total amount of services are 90000. Both the duration of a service and the service inter-arrival time follow the negative exponential dis-

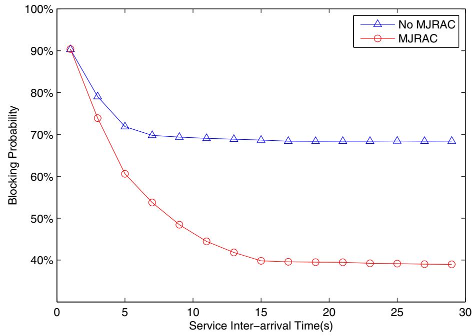

Fig. 6. BP of all services with/without MJRAC promotion

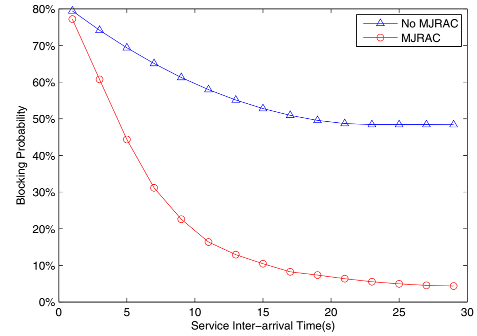

Fig. 8. BP of data services with/without MJRAC promotion

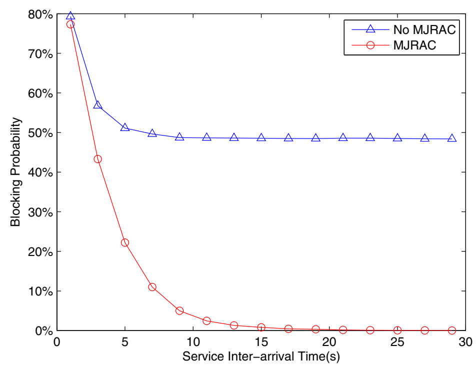

Fig. 7. BP of audio services with/without MJRAC promotion

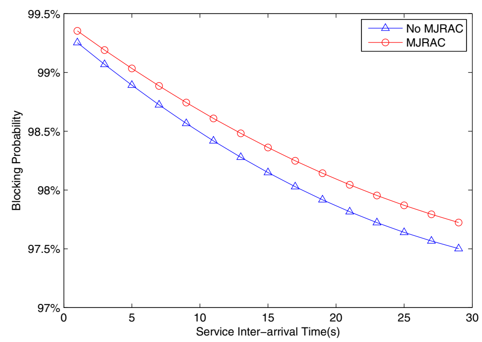

Fig. 9. BP of video services with/without MJRAC promotion

tribution. Two cases are compared based on different blocking probabilities (BP) of the coming services.

The overall service blocking probability diagram is shown in Fig. 6. The figure explicitly shows the advantage of MJRAC over the normal case. As the inter-arrival time becomes larger, i.e. cars are driving in an increasingly service-scarce environment, the average blocking probability of all the coming services can be reduced greater by using MJRAC. Also note that when the service inter-arrival time is increased to a specific value, BP value starts decreasing less and less. The advantage becomes constant when both of the two curves become flat. From the Fig. 6 we can approximately calculate out that MJRAC can help keep the blocking probability to the network 43% lower when compared with normal cases.

Fig. 7 to Fig. 9 show BP variations in terms of different kinds of services. In Fig. 7, where the services are audio services, the network using MJRAC has an obviously lower BP curve than the normal network. And similar with Fig. 6, the curve of MJRAC owns greater advantage than the normal one as the inter-arrival duration increases. The Fig. 6 clearly indicates that MJRAC helps audio services perform 100% better than the normal case at most, which is a huge advantage. Similarly, Fig. 8 also shows an obvious advantage of MJRAC data service case over normal data service case. So the BP performance of MJRAC case is optimized much better than that of the normal case.

Fig. 9 shows the poor performance of video service. It is because of the services relatively larger option rates or their narrow range of option rates, i.e. the required bandwidth of video service is extreme large. A larger option rate or a small number of data rate levels means more bandwidth needed, thus declining it may not be enough for a coming service to access. In this case, the drop of large option rates can only free up enough space for lower-data-rate services (like audio and data services) to be admitted. Therefore, MJRAC's QoS promotion is not the same when applying to different types of services. For a service that has relatively small data rates or a wide range of option rates, MJRAC works excellently; but for a service that has relatively large option rates or a small number of option rates, MJRAC gives less improvement in terms of BP values.

V. Conclusion

Based on the requirements of a VAN gateway and the demand on collecting heterogeneous network information, a cognitive VAN gateway was designed. The MJRAC algorithm with the multi-channel coordination was implemented in the cognitive VAN gateway, which has obtained more services admitted to the network and increased usage of the channels and proved by extensive simulations. It has also been identified that MJRAC was more effective on QoS promotion of the low-option-rate services in comparison with high-data-rate services. The overall performance of the services in the network was also greatly improved.

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