The Service Modeling and Scheduling for Wireless Access Network Oriented Intelligent Transportation System (ITS)*

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***Abstract*-This paper first describes the architecture and the main services of the wireless network oriented ITS (Intelligent Transportation System). The services of CVIS (Cooperative Vehicle-Infrastructure System) and PTT (Push To Talk) voice are analyzed and modelled. Pointed scheduling schemes are proposed for different services according to their QoS requirements. For CVIS service, vehicle speed adapted dynamic scheduling is adopted. For service of PTT voice, scheduling based on state transition is adopted. For video and other services which are not sensitive to delay, scheduling request is generated based on buffer status. Finally, the scheduling schemes are simulated on OPNET, from which the availability is verified with performance curve of delay and packet loss rate. And also, this provides reference for ITS access network design.**

***Key words* - Intelligent Transportation System (ITS), wireless access networks, QoS, Scheduling schemes, OPNET**

I. INTRODUCTION

In ITS[1] advanced information technology such as electronic control technology, data communication technology and computer technology in vehicle and road management is adopted to reduce traffic congestion and accident, and to save resource for improving environment. As one of ITS foundation, communication technology plays an important role in ITS, which is used to exchange information among vehicle and infrastructure.

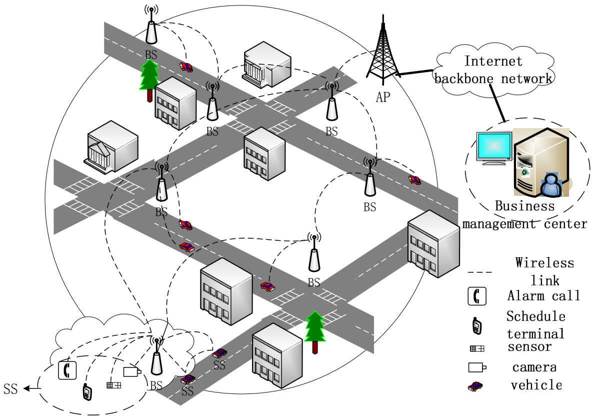

Figure 1. ITS access network structure

The ITS communication network structure[2] which is adopted in this paper is shown in figure 1. There are two types of SS (Subscriber Station) which are fixed type and mobile type. The fixed terminals include emergency telephones, sensors and cameras. And the mobile terminals include OBUs (On Board Units) in vehicle for CVIS and PTT terminals. The BSs (Base Stations) are in charge of data forwarding and form a wireless MESH network. Multiple SSs access the nearest BS through wireless link, which is called PMP wireless access network. The AP (Access Point) is the gateway between wireless MESH network and ITS backbone network.

*This work has been partially supported by science and technology projects of China Ministry of Transport (No. 2012-364-222-203).

II. SERVICES ANALYSIS FOR ITS WIRELESS ACCESS NETWORK

In ITS, QoS guarantee of the access network helps to provide timely and reliable information exchange. Table 1 describes the classification and characteristics[3] of services in ITS.

TABLE I
TYPES AND CHARACTERISTICS OF BUSINESS IN ITS

Types	content	characteristics
The service of CVIS	Vehicle identifier, vehicle GPS position, speed	Highest priority, related to vehicle speed
PTT voice	PTT voice	requires low latency
Video	Surveillance camera	Volatility, latency requirements
Other data	Sensor data	Low priority, low speed, stable

The data of CVIS service, which is most important in ITS, need to be timely exchanged among vehicles and infrastructure to improve traffic safety such as crash avoidance, and to reduce traffic congestion. PTT voice is used in trunking communication, the end-to-end delay of which less than 0.1s will not be aware of. The video service needs more bandwidth, but is not very sensitive with time delay because it's not interactive. The other data service has the lowest priority and low generating speed.

A. Service analysis and Modeling for CVIS

Service of CVIS has the highest priority. Enough channel resource must be allocated to it in scheduling design. Usually, higher upload frequency is needed for vehicle with higher speed.

Suppose the number of the vehicles within the range of a BS is n, which maximum is $N_{\max}$ when the road is in completely congested status. When n is very small the speed of vehicle v reaches its maximum: $V_{\max}$.

When n is small, the average speed μ of vehicles is large. With the increase of n, μ begins to decrease, which will fall to zero on the congestion status. The relationship between n and μ can be represented by traffic flow theory [4], which is:

$$\mu = V_{\max}(1 - \frac{n}{N_{\max}}) \tag{1}$$

According to traffic flow theory, in a certain range, all vehicle speed follows normal distribution, that is:

$$f(v) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(v-\mu)^2}{2\sigma^2}} \tag{2}$$

Where μ is average speed and σ is standard variances.

According to the above discussion, the upload frequency f should be determined by the speed v, high upload frequency with high speed. For study convenience, the relationship between f and v is defined as:

$$f = \frac{F_{\max} - F_{\min}}{V_{\max}} v + F_{\min} \tag{3}$$

Now the network traffic of CVIS can be concluded as:

$$s = n\int_0^{V_{\max}} (\frac{F_{\max} - F_{\min}}{V_{\max}} v + F_{\min}) \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(v-\mu)^2}{2\sigma^2}} dv \tag{4}$$

According to traffic flow theory, $\sigma << \mu$. Then:

$$s = n(F_{\max} - \frac{F_{\max} - F_{\min}}{N_{\max}} n) \tag{5}$$

The result above is that the offered traffic of CVIS and the number of vehicles have a quadratic function relationship. The offered traffic first increased and then decreased. When $n = \frac{F_{\max} N_{\max}}{2(F_{\max} - F_{\min})}$, the offered traffic reaches its maximum:

$$S_{\max} = \frac{{F_{\max}}^2 N_{\max}}{4(F_{\max} - F_{\min})} \tag{6}$$

B. Service analysis for PTT voice

PTT is introduced in ITS because it can play a important role in regular and emergency scheduling. To achieve push to talk, the access time must be less 1s. And the delay of speech frame on the link of wireless access network must be far below 0.1s.

PTT voice basically has two states: activation state and silent state [5]. These two states appear alternately. Voice packets are created periodically on the activation state, while packets of silent frame is created in far lower period on the silent state, as shown in figure 2.

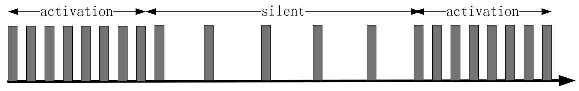

Figure 2. Voice of quantitative group

III. ITS MULTI-REQUEST(ITS-MR) SCHEDULING SCHEME

For downlink service scheduling, BS knows all arrived service data, and can complete scheduling alone. For uplink service scheduling, each SS sends the request of resource to BS, according to which BS allocate correspond resource to each SS. The uplink scheduling needs more control overhead and more coordination, which make it more complex than downlink scheduling.

ITS scheduling model with QoS guarantee is designed as in figure 3, reference to that of CHU [6].

In the uplink scheduling, the services is classified by SS. Different services flow into respective buffer queue. Resource request message is generated by SS for each buffered service and is sent to the BS in uplink sub-frame. For service of CVIS, the request message is implicit in each service data. PTT SS only need to report the status transition to BS with piggyback. For other two types of services, the queen length is reported to BS periodically using piggyback, for which EDF (Earliest Deadline First) [7] is adopted that means timeout packets need to be discarded.

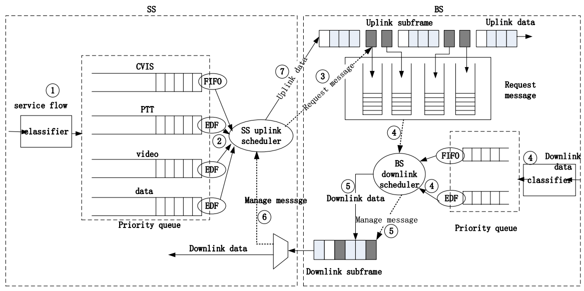

Figure 3. ITS scheduling model with QoS guarantee

BS receives the request messages from SS and allocate the resource accordingly. Then BS send these results in UL-MAP in downlink sub-frame. Each SS sends these packets which BS has allocate resource for.

The uplink scheduling of CVIS is shown in figure 4. Each OBU transfers one CVIS packet or not in the next uplink sub-frame according to received UL-MAP.

The packet of CVIS includes the identifier, position and speed of the vehicle. Once BS gets the speed, it calculates the serial number of frames away from this frame by the formula (3).

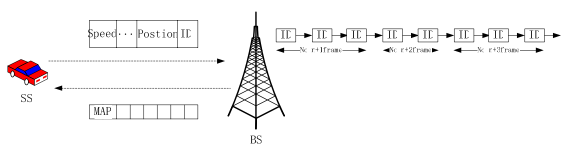

Figure 4. Uplink scheduling of CVIS

BS maintains a chained list, the node of which contains SS ID and the serial number of the frame to be allocated. Each calculation result is to be attached at the end of the list. BS will fill and broadcast the UL-MAP one frame in advanced according to the head of the list.

For PTT voice, the traffic in silent state is less than in activation state. So resource utilization will be low if fixed resource is allocated for both of the states. A scheduling based on state transitions is designed as shown in figure 5, reference to that of Dou [9].

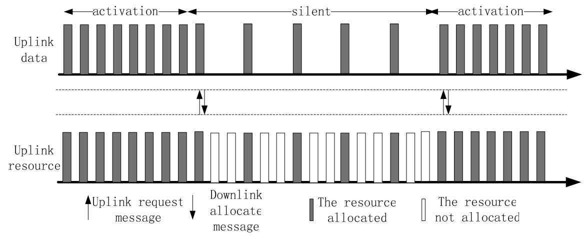

Figure 5. State transitions scheduling of PTT voice

This scheme takes advantage of the voice service features: the rate is unchanged during the activated state or silence state. SS only need to send the change of state to BS. And BS allocates different TDMA resource to SS accordingly. Only one downlink allocation message is needed in one state duration, which means very little overhead and no extra delay. The disadvantage of state transition scheduling is that it may introduce a small amount of packet loss on transition from silent state to active state. This small packet loss could be more tolerable because of the continuity of PPT voice.

ITS video mainly refers to monitoring video, which are not interactive. So it may need more bandwidth, and has a lot of volatility, but no restrict time delay is required. According to these characteristics, a buffer is set for generated video data. SS send the queen length of video data in the buffer, as shown in figure 6. The scheduling of other data adopt the same way to video.

BS first allocates the resources to services of CVIS and PTT voice, then allocates the rest to video and data services.

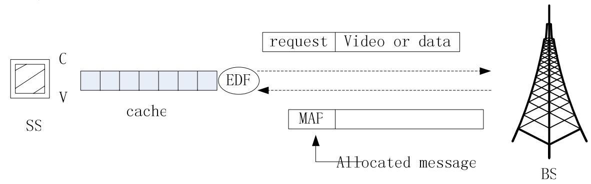

Figure 6. ITS video and data business scheduling scheme

IV. SIMULATION OF ITS-MR SCHEDULING

ITS-MR scheduling scheme is simulated on OPNET, to verify whether ITS-MR can meet the QoS requirements of ITS services.

In the scenarios, there are one BS, 336 vehicles with OBU, 3 PTTs, 1 video and 1 data. The simulation duration is 30min, in which the number of available OBUs increases from 0 to the maximum linearly.

Figure 7 shows the receiving rate of CVIS data. As the core Service of ITS, CVIS packet has highest priority to get the transfer resource. The throughput first increased and then decreased as which has been analyzed previously. The small fluctuations of the curve is the result of normal distribution of vehicle speed.

Figure 8 shows the simulation result of PTT voice delay, it can be seen from the figure that most of the PTT packet delay is less than 0.01s, which meets the requirements of PTT service.

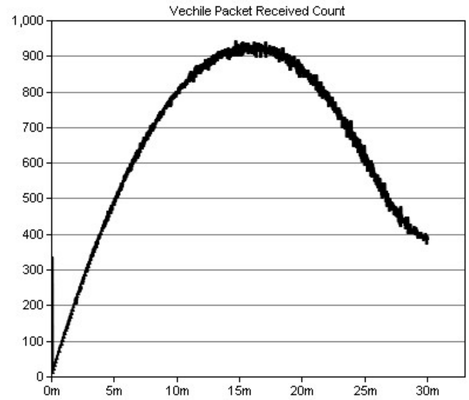

Figure 7. simulate results of CVIS service

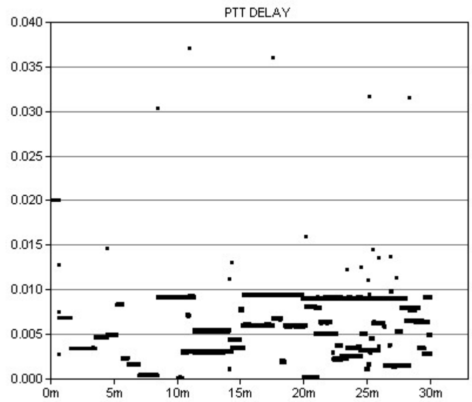

Figure 8. simulate results of PTT voice business

The comparison of generating and receiving rate of video service is shown in figure 9. The receiving rate curve is smoother than generating rate curve because of buffer adopted. It also can be seen that the delay is larger when CVIS service rate is larger in middle part of simulation duration.

The left part of figure 10 shows the additive comparison of generation amount and the reception amount of other data. Packet loss occurs in middle interval. The right part of the figure shows the packages delay has reached the maximum (5s) also in the middle interval. These are because that larger amount of CVIS data occupy more bandwidth.

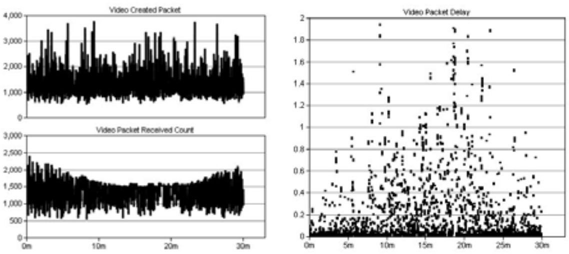

Figure 9. simulate results of video service

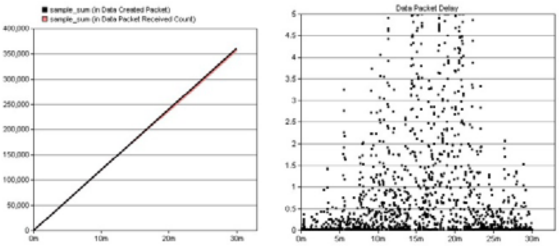

Figure 10. simulate results of data service

From the above simulation results, it can be concluded that ITS-MR scheduling scheme effectively satisfy the QoS requirements of each service. ITS-MR scheduling scheme provides a reference for the actual network design.

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