Broadband Mobile Ad hoc Network System for Emergency Communications

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ABSTRACT

This paper describes broadband mobile Ad hoc network system for emergency (or disaster) communications. The disaster communication network is based on mobile ad hoc network and the traffic will be increased and concentrated on specific site. For communication services under disaster circumstance, this paper considers mobility, variable packet length to reduce transmission overheads, dynamic routing protocol to provide efficient data transmission path and application-level support to provide real-time multimedia services. This paper adopts two-way satellite communication systems (forward link for DVB-S2, return link for DVB-RCS) for disaster communications. With these considerations, a disaster communication system can provide PPDR services efficiently in mobile ad hoc network environments.

Keywords: *Disaster communication, PPDR, Ad hoc network, two-way satellite*

1. Introduction

The disaster communication network for PPDR (Public protection and disaster relief) means a service network which is operated by governmental chain of command for supporting public safety via wire, wireless or interconnected network under disaster circumstance. The disaster communication network is based on ad hoc network and requires flexible network structure and traffic detour transmission for strengthening of network survival.

The traffic will be increased and concentrated on specific site in emergency state. For acceptance of inequality of traffic increasing, it requires efficient routing protocol and traffic distribution for emergency communication network.

2. Public Protection and Disaster Relief (PPDR)

2.1 Disaster Communications

The disaster communication is a communication system which works in emergency circumstance and it is composed of two parts; PP (Public Protection) and DR (Disaster Relief). The public protection communication for protecting life and property and maintaining order under emergency conditions and Disaster Relief communication will be used when the social function and public infra were destroyed by accident or natural disaster. The PPDR communications includes most kind of communications and the ITU-R classifies narrowband, wideband, broadband according to bandwidths.

2.2 Communication System

ETRI (Electronics and Telecommunication Research Institute) developed a mobile broadband two-way satellite communication system (DVB-RCS compatible) and the system overview is shown in Figure 1.

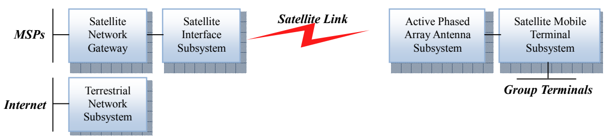


Figure 1. Components of Satellite Communication System

System Composition

A two-way satellite communication system is based on DVB-RCS (Digital Video Broadcasting-Return Channel via Satellite) specifications and divided into two parts – hub station and group terminal (RCST: Return Channel Satellite Terminal). The hub station is composed of terrestrial network subsystem (TNS), satellite network gateway subsystem (SNG) and satellite interface subsystem (SIS). The terminal group is composed of active phased array antenna subsystem (APA) and satellite mobile subsystem (SMT).

In the hub station side, the TNS connects DVB-RCS system to terrestrial network, the SNG passes data from Multimedia Service Provider (MSP), Internet Service Provider(ISP) or broadcasting TV to the SIS for transmission to terminal and the SIS sends data to satellite or receive data from it.

In the terminal side, the APA provides send/receive interface in mobile terminal with using active phased array antenna. And the SMT works as does SNG.

Each MSP which is located in hub station and ISP which are connected to internet use forward link for transmission data from hub station to group terminal. The SIS converts data and transmits to group terminal. An end-user who is located in terminal station use return link for transmission data to hub station. The SMT converts data for ATM cell and transmits them to hub station.

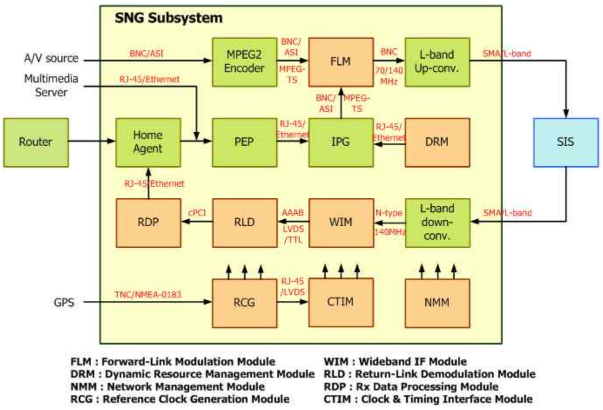


Figure 2. Block Diagram of Hub Station

3. Multimedia Services on Satellite communication environment

Most of PPDR services have multimedia features and in order to deliver multimedia traffic over broadband wireless networks, it needs sufficient bandwidth and support service-specific QoS requirements concerning delay, delay variation, and packet loss on a per-connection basis. The considerations for deliver multimedia traffic in each of the layer are as follows.

Physical layer

The radio physical layer is essential for wireless network. One wants to find a radio physical layer that is spectrum efficiency (bits per hertz), minimizes the radio overhead, and is robust in both indoor and outdoor environments. However, because of various channel impairments, it is very hard to get an optimal radio physical layer.

Data link layer

Data link control (DLC) is the core for multiplexing services with varying QoS demands. Although the specific scheduling algorithms should not be standardized, the DLC framework and interface parameters should be harmonized. A generic wireless DLC will consist of a flexible packet access interface, delay- and delay variation-oriented scheduling for multimedia traffic, and error control per service requirement.

In general, QoS control is taken care of by core network signaling. Ideally, one wants to find an appropriate DLC protocol that can (1) maintain some availability of the shared wireless resource using a multiple access technique and (2) at the same time provide added protection on the transmitted packets using error control to mitigate packet loss related to the fading of the medium.

Higher layer

Channel allocation is an important issue in radio resource management. It involves allocation the radio resources system-wide to achieve the highest spectrum efficiency. There are two basic forms of channel allocation, namely fixed channel allocation and dynamic channel allocation. Handoff involves all the issues associated with the mobility feature of wireless communications, such as location registration, update, paging, handoff, and call routing. This requires tracking the call to maintain connection and provide inter-cell handoff when needed. In order to maintain the desired QoS after handoff, a scheme called QoS-controlled handoff[9] may be required.

Multimedia-Related

Application awareness and adaptive streaming are two essential concepts in QoS provisioning in the multimedia wireless environment [10]. Dynamic bandwidth control ensures seamless end-to-end delivery of multimedia traffic over both wireless and wired portions of a communication path. The realization of end-to-end QoS control and the exploitation of scalable flows can be achieved through resource binding and provision of a set of QoS-aware adaptive algorithms, such as adaptive network services, and adaptive and active transport services. The latter in corporate a QoS-based application programming interface (API) and a full range of transport algorithms to support the delivery of continuous media over wireless networks. Flow control is important rate control exerted by a receiving system or network node (whether mobile or not) on the source sending the information. Control is typically exerted when a receiver is in danger of overflowing. This type of control cannot be exerted on real-time traffic such as video, which must be delivered with specified deadlines on time delay and delay jitter. It can be exerted only non-real-time traffic with relatively loose delay bounds.

4. Mobile Ad hoc Network for Disaster Relief

The disaster communication is a kind of mobile multimedia service and it must consider mobility, data transmission, routing path and multimedia service characteristics. The communication system under disaster environments need variable packet length to reduce transmission overheads, dynamic routing protocol to provide efficient data transmission path and application-layer scheduling to support real-time multimedia services.

Mobility in PPDR system

The terminals in PPDR system are a typical wireless network which have no fixed wire network and only composes of mobile hosts. It has MANET feature which can connect each other directly or by way of another mobile nodes in available radio area[3].

All of nodes in MANET have mobility and it causes variation of network topology as time goes by. And each of the nodes has restriction of a radius data transmission and effective data transmission by limitation of battery capacity, low bandwidth and high error rate.

In spite of these restrictions, the MANET can be used usefully in temporal and limited area such as disaster relief, battlefield, exhibition hall and etc. The characteristics of MANET are as bellows [4].

- Dynamic topology (needs various routing protocol)
- Terminal works as a host or router
- Bandwidths are limited and variable
- Each of nodes has energy restriction

Generic Stream Encapsulation

The first generation of DVB standards supported data transport using the MPEG format (see ISO/IEC 13818-1 [2]), with a Transport Stream packet multiplex (MPEG-TS). Multi Protocol Encapsulation (EN 301 192 [3]) is the DVB standard for encapsulation of audio/video and other content on MPEG-TS packets. The second generation of DVB standards features backwards compatibility modes for carrying MPEG-TS as well as generic modes for carrying arbitrary packets of variable length. These are referred to as Generic Streams (GS).

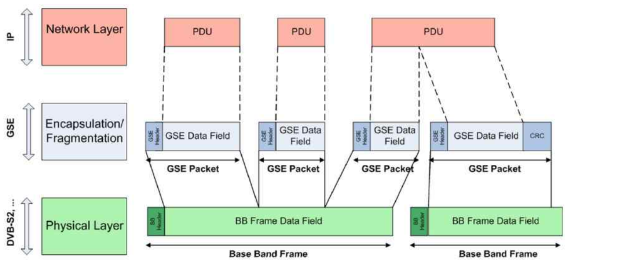


Figure 3. GSE encapsulation within DVB protocol stack [4]

The GSE protocol has been devised as an adaptation layer to provide network layer packet encapsulation and fragmentation functions over Generic Stream. GSE provides efficient encapsulation of IP datagrams over variable length Layer 2 packets, which are then directly scheduled on the physical layer into Base Band frames.

In addition to the overhead reduction, GSE provides a more efficient system operation for interactive systems that utilize advanced physical layer techniques such as for instance Adaptive Coding and Modulation (ACM). The inherent channel rate variability experienced in ACM systems makes the Generic Stream format more suited than the Transport Stream. GSE provides a flexible fragmentation and encapsulation method, which permits use of a smart scheduler to optimize system performance, either by increasing the total throughput and/or by improving the average packet end-to-end delay. In addition, GSE flexibility leads to a reduction in packet loss under fading variations, allowing the scheduler at the transmitter to dynamically change transmission parameters (for example modulation format, coding rate) for a particular network layer packet.

Network Synchronizations

A satellite return link which uses DVB-RCS must maintain synchronization for using lots of timeslots in superframe. The purpose of network synchronization is making the terminal time equal to network clock reference (NCR) of hub station for reducing jitters in return link.

NCR Insertion

The system uses DVB-S2 which supports CCM mode as well as ACM and VCM mode for forward link. In CCM mode, it can insert NCR periodically because all lengths of PL-frames are same. But in ACM or VCM modes, it is difficult to insert NCR periodically because each length of PL-frames is various.

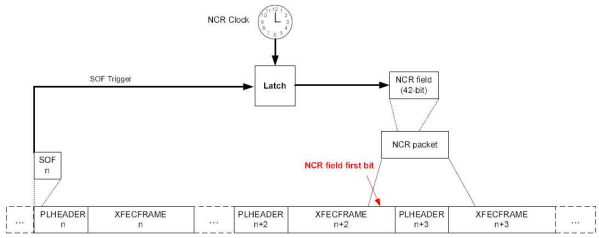
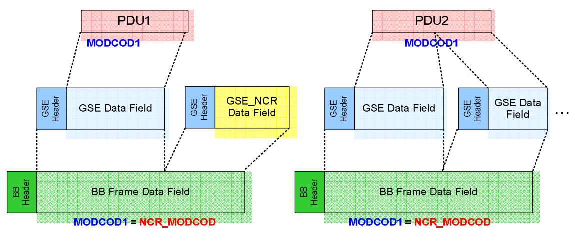


Figure 4. Relation of SOF and NCR in sender-side

The DVB-RCS specification inserts current NCR value after next two PL_FRAME (Figure 4). The insertion of current NCR value in a frame is impossible because the frame was composed before SOF (Start Of Frame) is transmitted. If the NCR is inserted in a BB_FRAME generation step, it occur processing delay for making FEC_FRAME and PL_FRAME. This delay will make ambiguous jitters because it is not regular in each of FRAME. In other words, a NCR insertion moment not always meets $n+1$ FRAME period caused by symbol length of BB_FRAME and FEC code rates. For removing the ambiguity, a NCR value is inserted after $n+1$ Frame.

The NCR must be encapsulated in GS packets and Fig 5 shows GSE_NCR container and GSE Encapsulation (single MODCOD and multi MODCOD) with NCR.



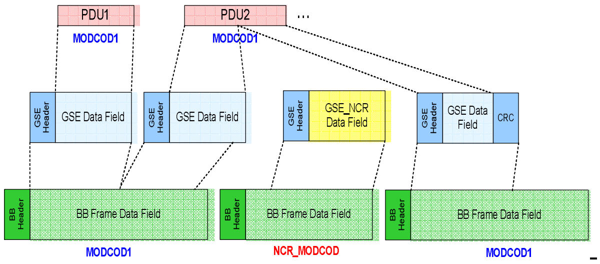


Figure 5. Relation of SOF and NCR in sender-side

Acquisition of basis time (NCR Recovery)

In VCM or ACM mode in DVB-S2, a NCR cannot be transmitted with precise fixed duration because different lengths of PL-FRAMEs are transmitted. That is the reason why a SOF time which is transmitted SOF of PL_FRAME inserted in next PL_FRAME and transmitted. The numbers of passed PL_FRAMEs are not regular according to the structure of receiver.

This paper uses window for mapping of SOF reception time and NCR. When a receiver receives each of SOF of PL-frames, saves SOF reception time as much as reception window size with local clock and the oldest one will be updated with a new one.

When a difference of SOF times and difference of NCR times are equal, it can find out the SOF which sent NCR. But, the differences are not precisely matched caused by jitter. Accordingly, if the differences are located in an acceptable error range, we acknowledge the SOF matched with NCR and modify the local clock for the jitter.

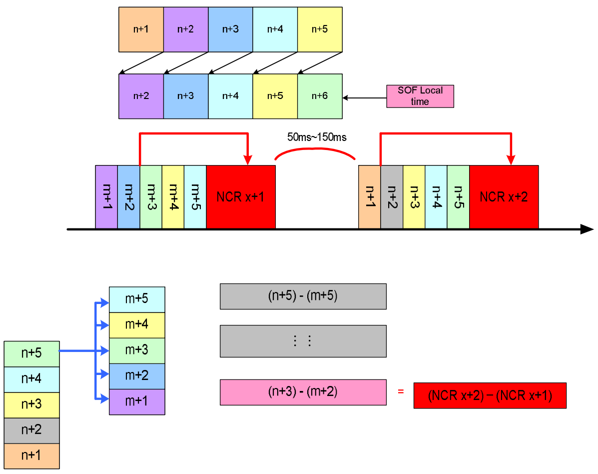


Figure 6. Matching of SOF and NCR

$$\{(n+3)-(m+2)\}-(NCR_{x+2}-NCR_{x+1}) = jitter$$

Delay can be expressed as below and jitter range can be changed in sending/receiving each of any frames.

$$Delay = Propagation\ delay + processing\ delay + Jitter$$

Routing Protocol

For minimizing the connection refusal and packet loss in frequent movement in mobile terminal, many kinds of routing protocols were proposed. The protocols can be classified into proactive (table driven) and reactive (on demand driven) method according to management of routing table.

Proactive method

Proactive method maintains latest routing information by managing it continuously but it uses considerable network capacity for this. Also, it is increasing of not-used probabilities when nodes are moving fast and the overhead will be increased as the nodes are increasing. The representative protocol in proactive methods are OLSR (Optimized Link State Routing Protocol) and TBRPF(Topology Dissemination Based on Reverse-Path Forwarding).

Reactive method

Reactive method performs path establishment process when it has requirement and solves excess traffic transmission problem compare to proactive one. But it takes much time for gathering latest routing information and this is the reason that research for optimized path search and minimizing the search delay is going on. The representative protocol in reactive methods are DSR (Dynamic Source Routing) and AODV(Ad hoc On Demand Distance Vector).[8]

Real-time Multimedia Services Support

The disaster communication has multimedia service characteristics and it is need that deadline control, real-time scheduling policy and resource management for supporting real-time services. Some QoS parameters in multimedia services which are requested by user can affect deadline of the other tasks in a system. A resource management (monitoring, allocation and release) is necessary for supporting QoSs which are requested by a user.

The resource management can be provided by operating system or service management as a middle-ware in user-level. The former can maximize performance improvements, but modify the current operating system. This makes operating system larger and it is also difficult for supporting each of the requirements which are requested by various applications. The latter can support real-time service without modification of operating system and perform scheduling and resource allocation on application level. Like the latter case, we adopt user-level real-time scheduler (URES) and resource management. These give hints to the operating system for selecting thread which will be work on next time and this reflects user's intention.

The Figure 7 shows the user-level scheduling control steps between client and server. The URES in client side executes local scheduling and in server side does global scheduling. We use Earliest Deadline First (EDF) algorithm for URES.

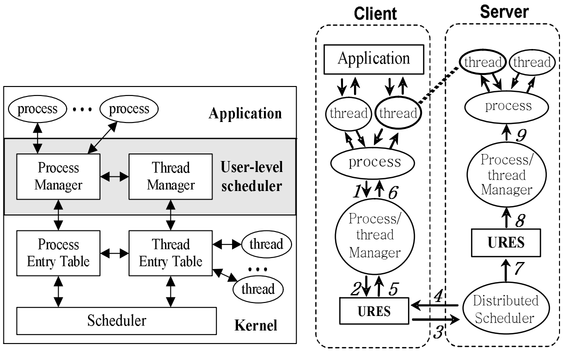


Figure 7. User-level real-time scheduler

The scheduling targets of URES are application-level processes except system processes. The processes and threads information are maintained on process entry table and thread entry table in kernel. The URES changes the priority of user process/thread and the changed information will be registered in process/thread entry table in kernel. The priority changed processes will be scheduling target by kernel. This reflects user intention.

5. Mobile Ad hoc Network System for Disaster Relief

The Figure 8 shows the compositions of mobile ad hoc network system for disaster relief. The PPDR servers are located in hub station side and mobile group terminals are located in terminal side (disaster area).

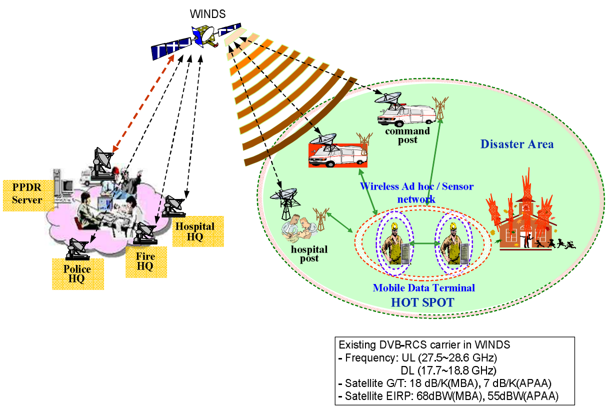


Figure 8. Satellite communication system for Disaster Relief

The Figure 8 shows the compositions of mobile ad hoc network system for disaster relief. The PPDR servers are located in hub station side and mobile group terminals are located in terminal side (disaster area).

Experiments for Disaster Communications

The experiments were progressed in next steps;

- Measurement of throughput gain of IP over MPEG-2 TS and GSE
- Measurement of error count of NCR insertion & recovery method
- Measurement of packet delivery ratio of dynamic routing algorithms (simulation)
- Measurement of deadline violation tasks with URES

When the system use GSE, the overall throughput gain is better than MPEG2-TS approximately 3 % to 10 % with the variable length Layer 2 packet size in DVB-S2 system.

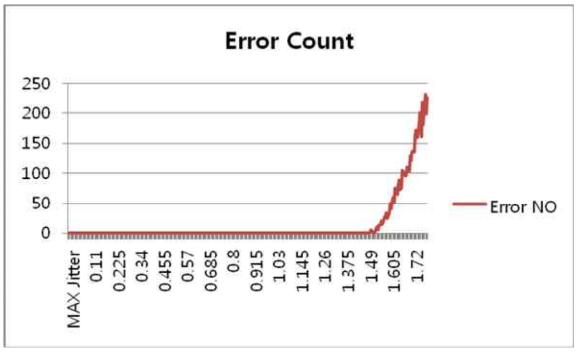


Figure 9. Results of NCR recovery

The jitters are generated in *Min~Max* jitter range and evaluate the error rates according to the jitter variation. A mismatching of NCR packet started to occur when the Max_Jitter was 1.5010000 *us*. As a result, the valuable NCR packet recovery ranges are -1.5*us* ~ 1.5 *us*. It can recover a NCR packet when the jitter is 0 and -1.5 *us* ~ 1.5 us with this NCR recovery methods.

For the performance evaluation of dynamic routing algorithms for emergency communication, we did a simulation. The simulation composed ad hoc network according to WIDENS (Wireless Ad Hoc Network for Public Safety) and MESA SoR (Statement of Requirements) disaster scenarios. [13][14]

As a result of simulation, the OLSR has better packet transmission rate than the DSR. The DSR does source routing which establishes transmission path before it works. If one of node has out of transmission range, it lost packets with this source routing. But this configuration had unlimited buffer size and finished traffic generation before the simulation finished for gathering transmission-completed packet rate.

Figure 11 shows End-to-End delay of DSR and OLSR. In the figure 12, The vertical means the number of nodes which have video traffic (100*Kbps*) and the horizontal means average transmission delay(*msec*). The system already using 0~500*Kbps* bandwidth because all of nodes have 1*Mbps* transmission rates and generates voice traffic (10*Kbps*). As a result of simulation, the DSR has better transmission delay than the OLSR. The reason is that the DSR is a reactive method and the OLSR is a proactive one as mentioned before. The traffics for maintain routing table in OLSR causes transmission delay.

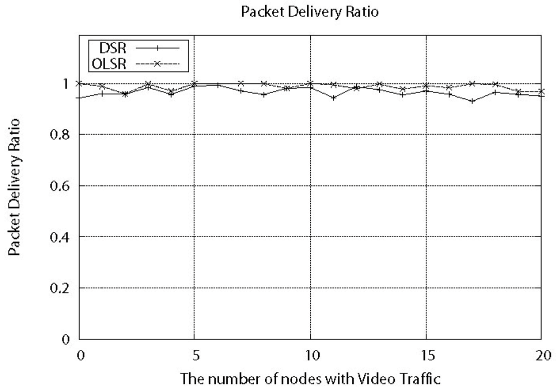


Figure 10. Packet transmission rates of DSR and OLSR

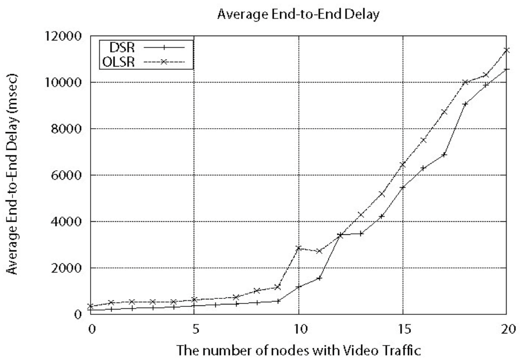


Figure 11. Average End-to-End delay of DSR and OLSR

For real-time services, we measured deadline violation tasks. Each side of the hub station and terminal, we ran Stream server and client. Each of the multimedia data which will be processed in application has its own deadline and priority. If a task does not be allocated resource before its deadline, we regarded as deadline violation tasks. According to the experimental result, the numbers of deadline violation tasks are decreased as 14.6% with user-level real-time scheduler.

6. Conclusions

The disaster communication network is based on ad hoc network and the traffic will be increased and concentrated on specific site. For communication system under disaster circumstance, this paper considers mobility, variable packet length to reduce transmission overheads, dynamic routing protocol to provide efficient data transmission path and application-level support to provide real-time multimedia services.

This paper uses mobile two-way satellite communication system (forward link for DVB-S2, return link for DVB-RCS) for disaster communication and generic stream encapsulation (GSE) for packet overhead reduction. A satellite return link which uses DVB-RCS must maintain network synchronization for using lots of timeslots in superframe and this paper shows how to insert and acquisition of NCR with variable packet length.

The traffic will be increased and concentrated on specific site in emergency state. For acceptance of inequality of traffic increasing, it requires routing protocol and traffic distribution for emergency communication network. This paper simulated OLSR in proactive and DSR in reactive and validated the performance in disaster environment. The disaster communication has multimedia service characteristics which need deadline control, real-time scheduling policy and resource management for supporting real-time services. This paper shows URES which give hints to the operating system for selecting thread which will be work on next time and this reflects user's intention.

In conclusion, this paper shows what we have to consider for disaster communication services in mobile Ad hoc network and evaluates performances which are considered. The system with GSE, the overall throughput gain is better than MPEG2-TS with the variable length Layer 2 packet size in DVB-S2 system and the valuable NCR packet recovery ranges are -1.5 *us* ~ 1.5 *us*. It can recover a NCR packet when the jitter is 0 and -1.5 *us* ~ 1.5 *us* with this NCR recovery methods. The DSR has larger packet loss rates than the OLSR but has fewer amounts of lost traffics. The OLSR can route more safely than the DSR but it has traffic loss peculiar to proactive method. And also the numbers of deadline violation tasks are decreased with user-level real-time scheduler.

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