Ad hoc and Ubiquitous Communication Environment supported by Data-Driven Networking Processor

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Abstract-**This paper proposes the necessity of the secure, ad hoc and ubiquitous communication environment that is integrating personal authentication and usage right management onto the mobile ad hoc network, which is an infrastructureless network suitable to the emergency cases. To implement this environment, this paper studies technical requirements to each layer and among them it proposes two basic ideas. One is the reliable information transmission over the ad hoc network. We propose to combine Multiple Description Coding (MDC) with multiple source transport in order to maintain a smooth video streaming over wireless ad hoc networks. The other is the data-driven platform to support communication environment, which achieves efficient real-time multi-processing capability without any runtime overhead based on the passive or data-driven execution mode.**

I. INTRODUCTION

It becomes realistic to have a ubiquitous networking society which people can take advantage of information sharing environment anytime and anywhere [1]. The studies so far, however, mainly tackled so-called infrastructure-based environment. A mobile ad hoc network is an infrastructureless one and is a group of wireless devices that organize themselves in a mesh topology to find routes and relay packets from a node to any other node.

This paper handles this infrastrucreless communication environment that can work even in case of emergency where existing infrastructure cannot be available. To achieve this communication environment, comprehensive study must be necessary from the hardware platform through the network layer to application.

First, the hardware platform [2][3] that will support the communication environment will have to be tolerant to multiprocessing and congestion of processes in unstable condition of emergency case, and consume as little electric power as possible. The data-driven processor [4][5] which one of the authors has been tackling will become a powerful candidate platform to fulfill these requirements. The authors have been developing the CUE-v2 microprocessor performing both as dataflow and as superscalar using common pipeline resource. The CUE-v2 retains the advantages of dataflow architectures, e.g., fair multiprocessing with no context switching overheads, and achieves the speedup of sequential processing by combining a superscalar execution mode. That is, the CUE-v2 was realized as a hybrid processor enabling simultaneous processing of data-driven and control threads to achieve higher performance for inline processing and to avoid any bottlenecks in sequential parts of real-time programs frequently encountered in actual time-sensitive applications.=Based on the CUE-v2, we are planning to develop CUE-v3 as a chip multiprocessor to satisfy ad hoc and ubiquitous communication environment.

In the network layer, mobile ad hoc networks emerge as a promising solution for providing ubiquitous communications in case of emergency and the ability of ad hoc networks in supporting various multimedia applications, including video applications, becomes a topic of intense interest.

Considering the problem in emergency case, it is highly required to find such important information as where water, food, shelter, medicine, and hospitals are. Hence, information discovery mechanism of ad hoc network is an indispensable issue in emergency.

After information discovery, video transmission over infrastructureless ad hoc networks begins.

We are considering to adopt the Multiple Description Coding (MDC) [6] scheme replace conventional video coding scheme where several independent and equally important video streams (also known as descriptions) are generated in such a way that each description can be decoded to its original video at low but acceptable quality, and any additional descriptions received increases the video quality on top of the minimum level .

We present another alternative to tackle this problem, M2P (multipoint-to-point) transmission. Each node can obtain data freely from any node as long as there is a valid route between them. In addition, if the same information is owned by several nodes within the network, a node can retrieve this information at higher rate by downloading it simultaneously from all these nodes, using the same concept as peer-to-peer network. Therefore, we propose M2P transmission for video streaming over mobile ad hoc networks

In upper layer, it will be required to have some authentication mechanism without usual security infrastructure such as PKI (Public Key Infrastructure) because even in emergency minimum security will be assured.

Among these discussion items, this paper tackles network and hardware platform layers. Section II discusses the requirements to the communication environment over ad hoc network. Section III describes data-driven processor platform to achieve the requirements. Section IV proposes M2P information transfer mechanism with MDC over ad hoc network architecture. Section V summarizes the discussions.

II. REQUIREMENTS FOR AD HOC AND UBIQUITOUS COMMUNICATION ENVIRONMENT

2.1. Requirements for the hardware platform

In the infrastructureless communication environment, especially in case of emergency, hardware platform [2][3] must be tolerant to heavy load and simultaneous multiple processing such as many node discovery message handling and frequent routing information control to establish mobile ad hoc network as described in 2.2.

Since ad hoc networks always exchange and process network configuration information such as routing messages, it is not desirable for normal processing to be loaded by the network configuration processing.

Moreover in some case, it may be very effective to continuously execute the pattern file checking for internet virus and worms in the hardware layer in order to keep security and safeness in the overall ad hoc network.

Hence, real-time multi-processing capability without any runtime overheads is required for the hardware platform.

Also in emergency, power feeding also becomes a problem. The hardware must reduce as much as power consumption as possible.

2.2. Requirements for the network layer

In the initial stage of the emergency ad hoc network establishment, it is likely that nodes do not know who are in the same ad hoc network. Especially in the case of emergency, there is a case where specific address is not necessary but specific information owned by the nodes is. For example, people would like to know where medical doctors are, where drinking water is, and so on. They need no specific IP address. This is information or contents discovery mechanism which must be required in the emergency network.

This type of discovery mechanism is generally adopted in the P2P environment using the existing infrastructure but not well discussed for the ad hoc network.

And after information discovery, layer 3 routing must be executed. We discuss the case where stream information such as video is transferred over the ad hoc network. To maintain the quality of the video over unstable wireless ad hoc network in which each node moves and so the link may often disconnected. Existing solution is the usage of diversity. MDC is realizing the content diversity. In order to fully utilize the strength of MDC scheme, these descriptions should be sent at highly disjoint routes to ensure a single route failure affect only a minimum number of descriptions. However, in this method, information is sent from only one node. So, if the source is disconnected from the route, information transfer cannot be made at all even if the route diversity is kept. Hence some mechanism to ensure the information transfer even in case of one source is gone. Information sender diversity must be considered.

III. MULTIMEDIA NETWORKING-ORIENTED DATA-DRIVEN PROCESSOR: CUE

To satisfy the requirements in section II, the authors are carrying out CUE (Coordinating Users' requirements and Engineering constraints) project. This research currently aims at building ubiquitous networking-oriented data-driven real-time execution platform.

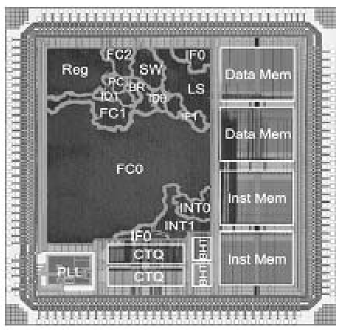
In order to keep maximum throughput in our data-driven processor, the basic design target for real-time multiprocessing scheme was chosen so as to alleviate any runtime overheads and to achieve real-timeness in the protocol handling without any supervisory controls.

Finally, data-driven parallel realization of protocol handling demonstrated efficient real-time multi-processing capability without any runtime supervisory control as long as data length is appropriate as shown in [7].

Also, it is apparent that sequential parts of real-time programs frequently encountered in actual time-sensitive applications such as connection/port management in TCP and the serialization of parameters in video compression result in bottlenecks in data-driven execution.

To alleviate this issue with retaining the advantages of pure data-driven architecture, architecture of the latest version named CUE-v2 [4][7] was established as a hybrid processor enabling simultaneous processing of data-driven and control-driven threads to achieve higher performance for inline processing and to avoid any bottlenecks.

The prototype chip was developed by employing standard-cell design, and it was implemented using timing-driven synthesis/layout. Crosstalk, antenna effect, and voltage drop were analyzed and validated using commercial EDA tools. The chip is built in a generic 0.18um six-metal layer process, the die size of 5 x 5 mm2, including 64 kbyte SRAM, and is packaged in a ball grid array having 292 pins. The chip layout is shown in Fig.1.



IF0,1: Instruction Fetch 0,1 ID0,1: Instruction Decode 0,1
FC0,1,2: Firing Control 0,1,2 INT0,1: Integer 0,1 LS: Load/Store
BR: Branch Reg: Register file CTQ: Control Thread Queue

Fig. 1 Layout image of the CUEv2

The CUE-v2 chip will be installed to a PCI board, which was originally designed in the CUE project, to be examined for its potential capability as chip multi-processor core in the next generation CUE-v3, which will achieve around 40 Giga bit per second through wireless network interface.

In CUE project, elastic pipeline realization has been experimentally verified for turn-around time and throughput in a circular pipeline adopted as a chip multi-processor core in the CUE-series data-driven multi-processors. Through VLSI realizations of CUE-p and CUE-v1, the turn-around time keeps minimum value as far as over loaded condition is avoided. This nature of the pipeline fully utilized in the real-time multiprocessing discussed in Section 2.1. Also, it was experimentally verified that power consumption of our data-driven processors was in proportion to throughput achieved in the pipeline. This feature and passive operation mode in ready-to-fire principle of the data-driven scheme will be effective to minimize power consumption at standby time.

Fully utilizing throughput, multi-processing capability and real-time responsibility, CUE-v3 will be one of the most promising platform to realize the robust ad hoc network in our project.

IV. M2P INFORMATION TRANSFER OVER AD HOC NETWORK WITH MDC

To satisfy the requirement 2.2, what the keys for discovery are is considered. First, the specific information owned by each node is the most possible key. For instance, people want to know where medical doctors are, where drinking water is, and so on. Second, the specific group is also a good key for discovery. You would like to discover your community such as your company, school, and so on. Third, specific names and addresses could be used. We propose a mechanism of discovery for two directions. One is "push" typed, the other is "pull" typed.

As for the push typed discovery, we have already proposed Words-of-mouth information sharing mechanism based on OLSR-MPR [8]. Information owner broadcasts a PUSH packet informing the fact that he has the information or catering information itself by using flooding mechanism.

We also added inquiry mechanism in the above mechanism, which will be categorized into Pull mechanism. When people would like to know a place where specific information is, he sends a PULL packet for inquiry. If MPR nodes hearing this PULL packet have cache of a PUSH packet which contains same information as the PULL does, they will at once send back the PUSH packet to the PULL sending node.

To fulfill the requirement after discovery of information, instead of using only one video source to send the multiple descriptions of video, we propose the use of multiple sources, where each source will send a unique MDC-coded description of the video. This aims to obtain better load balancing within the network and to increase the probability of receiver meeting with the video sources. One drawback of multiple descriptions coding is higher overhead due to larger number of packets. Considering the tradeoff between performance and overhead, two-description is a common and practical model.

To fulfill the requirement in section 2.2, instead of using only one video source to send the multiple descriptions of video, we propose the use of multiple sources, where each source will send a unique description of the MDC-coded video. This aims to obtain better load balancing within the network and to increase the probability of receiver meeting with the video sources. One drawback of multiple descriptions coding is higher overhead due to larger number of packets. Considering the tradeoff between performance and overhead, two-description is a common and practical model.

Simulation study has been carried out using NS2 [9] with CMU wireless extension[10]. The routing algorithm used is Dynamic Source Routing (DSR). because it has been proven to outperform table based approaches in many scenarios. Anyway, the choice of routing algorithm is not the concern of this paper. The proposed mechanism can also be implemented using other routing algorithms without any constraints. The comparison study is carried out among single-sender-single-description (CASE I), single-sender-two-description (CASE II), and two-source-two-description models (Case III: our proposal). The simulation scenarios are designed carefully to perform the desired comparison fairly at six levels of node mobility, ranged between 5m/s and 20m/s.

The evaluation is based on the following two parameters: the number of bad periods and the average length of bad periods. A bad period is defined as a period in which one or more consecutive packets are lost. The number of bad periods indicates the number of interruptions occur during video streaming. Meanwhile, the average length of bad periods indicates the average interval of the interruptions. Simulation results show that the proposed mechanism reduces the number of bad periods by 30-50% and shortens the average length of bad periods by 10-30%, as compared to single-source single-description (Fig.2 and 3) [11].

V. CONCLUSION

This paper discusses the requirements to implement ad hoc and ubiquitous communication environment and possible solutions especially related to the layers of network and supporting hardware platform.

One of the main ideas is the data-driven platform to support the ad hoc and ubiquitous communication environment, which achieves efficient real-time multi-processing capability without any runtime overhead based on the passive or data-driven execution mode. By virtue of the processor, we apply it to continuous packet filtering for security and multiple job handling.

The other is the information discovery in an emergency case and M2P with MDC information transfer over ad hoc network to assure minimum quality of video sending. We propose the use of multiple sources to deliver multiple descriptions video over wireless ad hoc networks. Simulation result shows that the proposed mechanism improves the quality of video streaming.

By combining these ideas, we believe we can establish a new paradigm for emergency information sharing. We are going to implement proposed systems to show the effectiveness.

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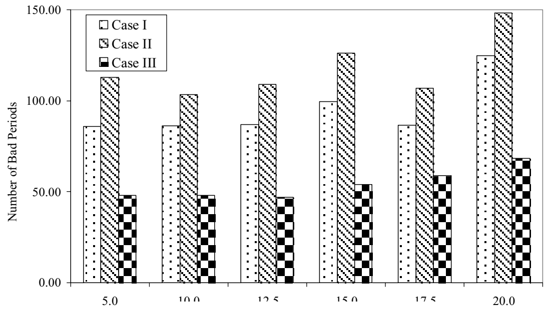

Fig. 2 Number of Bad Periods

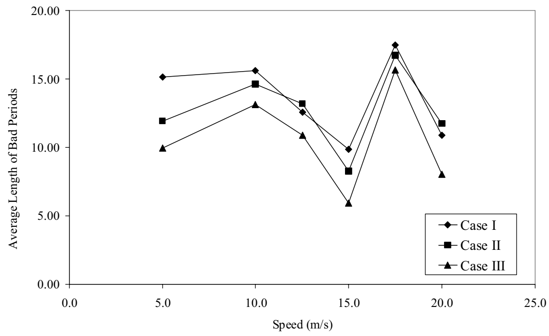

Fig.3 Average Length of Bad Periods