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Protocol Optimization for Integrated Heterogeneous Networks in Disaster Areas

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I. Introduction

In East-Japan Catastrophic Disaster in March 2011, the earthquake and tsunami dramatically affected communication infrastructures. Although cellular networks were available in some areas, network operators restricted call requests due to heavy network congestions. We experienced and learned that it is impossible to respond to dramatically increased communication demand only by using cellular networks, which implies the need of integrating any available networks to provide a huge number of people in disaster areas with network access services. To this end, we focus on an integrated heterogeneous network constructed by connecting regional networks deployed in stations, offices, etc. In such network, protocol optimization is a significant issue to achieve highly efficient utilization of network resources because the available resources are limited due to the damages of disasters and unstable power supply. In this research, we aim to optimize network protocols used in regional networks in terms of improving communication efficiency in the integrated heterogeneous network allowing network access in disaster areas.

II. Integrated network in disaster area

We consider a joint network constructed by combining surviving network infrastructures as shown in Fig. 1. Assume that different network systems, such as 3G cellular, Worldwide Interoperability for Microwave Access (WiMAX), Wireless Fidelity (WiFi), can be used in each regional network with different network structures, e.g., tree-based, wireless mesh, ad-hoc, etc. Satellite networks are also considered as a solution to connect isolated areas to each other. Thus, it is clear that the characteristics of regional networks are totally different, which makes it hard to control Quality of Service (QoS) depending on the link capacities, message delivery delays and jitters, transmission reliability, and so forth. On the other hand, we need to pay attention to unusual users' geographical distribution. In the areas damaged by earthquake but not hit by tsunami, some people may take shelter and stay there for a long time, but others might determine to remain in their home. Furthermore, they will frequently look around to get water, foods, information, etc. It is assumed that users' density can be different from place to place, and change hour by hour. While the traffic load to each regional network is affected by such users' distribution changes, it is almost impossible to frequently change the resource allocation in the networks. How to efficiently utilize already deployed and limited network resources is a significant issue.

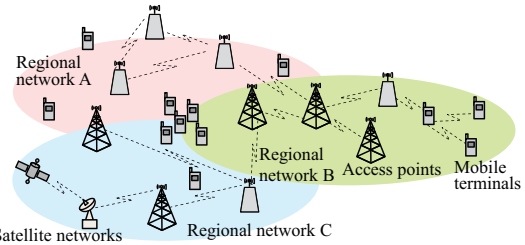

Fig. 1. An example of network environment.

III. Research objects

In this research, we address the following three challenging issues: traffic distribution, user terminal cooperation, and utilization of satellite networks. Since there is a gap between network resource and traffic demand distributions, network congestions will occur without any traffic distribution/detouring mechanism. Traffic load balancing among regional networks is necessary to maximize network resource utilization. On the other hand, user terminal cooperation is another solution to mitigate network congestion. Multihop wireless relay technologies allow users to communicate through other terminals, which contributes not only to virtually expand the coverage area of an integrated network but also give them a choice of regional network that they are going to utilize. Both regional network selection algorithm and routing protocol need to be optimized together to achieve effective load balancing. The last technical issue is how to utilize satellite networks as links connecting isolated regions with outsides. Due to smaller capacity of satellite links than that of terrestrial infrastructures, we need to highly utilize all available satellite networks, and optimize the interconnection with the integrated regional networks.

IV. Conclusion

This paper introduced the overview of the research which aims to provide us with network connections even if cellular systems are under heavy traffic congestions after disaster impacts. The integration of available regional networks has a good potential to achieve the goal. The protocol optimization is essential to efficiently utilize the limited available network resources. Traffic distribution, user terminal cooperation, and satellite network utilization are key technologies. This work belongs to the national project, Research and development of technologies for realizing disaster-resilient networks, supported by the Ministry of Internal Affairs and Communications (MIC), Japan.