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Mission Critical Ad-Hoc Networks Routing Protocol Optimized For Delay Sensitive Applications

Thesis submitted as a partial fulfillment of the requirements for the degree of Master of Science in Computer and Information Sciences

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Abstract

Increasing the throughput is an important objective for wireless ad-hoc networks. Many methods have been innovated for this purpose and on top of them is the network coding.

The existing network coding schemes, such as COPE and its updated versions, have succeeded to provide a remarkable throughput gain in case of unicast flows, while they failed to provide the same performance in case of the multicast scenario.

With the notable flourish of conference-based and multimedia streaming applications that are mainly depending on multicast flows, it becomes crucial to find a method that is able to deal efficiently with both unicast and multicast flows.

In this thesis, we provide a novel enhanced network coding scheme, which we call Graph-Based Network Coding "GBNC" that is able to handle both unicast and multicast flows simultaneously with the same performance.

The proposed scheme incorporates the graphic theory and the elimination technique to efficiently discover all possible coding opportunity and avoid the draw backs of the previous coding methods. It even provides the option to favor one type of flow over the other when needed.

The extensive simulation results reports the ability of the proposed scheme to achieve similar throughput gain to that of COPE in unicast flows and nearly double the gain in case of multicasting.

Contents

List of Figure

CHAPTER 1
INTRODUCTION

1.1 Motivation

The last few years have witnessed an explosive growth in the development and deployment of networked applications that transmit and receive audio and video content over the Internet. New multimedia networking applications (also referred to as continuous media applications)--entertainment video, IP telephony, Internet radio, multimedia WWW sites, teleconferencing, interactive games, virtual worlds, distance learning, and much more--seem to be announced daily. The quality of service requirements of these applications differ significantly from those of traditional data-oriented applications such as the Web text/image, e-mail, FTP, and DNS applications. In particular, multimedia applications are highly sensitive to end-to-end delay and delay jitter, but can tolerate occasional loss of data. These fundamentally different service requirements suggest that the WLAN network architecture that has been designed primarily for data communication may not be well suited for supporting multimedia applications. Applying network coding on WLAN would highly affect the throughput and will allow for much better support of modern applications mentioned earlier.

1.2 Problem Definition

WLAN have been designed following same principles of wired networks where the protocols of wired networks have been grafted onto WLAN. The different nature of the wireless medium where most of the links are broadcasting, in contrast to unicast links found in wired networks, have caused conflict between the wired network design and the characteristics of the wireless medium. This conflict combined with limited bandwidth and resources make WLAN suffer low throughput.

In order to support modern applications demanding high throughput requirements, it becomes a necessity to maximize the throughput and efficiently make use of the intrinsic characteristics of WLAN. This research aims at increasing the

throughput gain achieved from applying network coding to WLAN by using a novel network coding scheme.

1.3 Research Objectives

The objectives of this research can be summarized in the following points:

- To examine different techniques and methods used to enhance the throughput performance of WLAN.
- To improve the throughput gain of the most promising approach.
- To evaluate the achieved results in comparison with the modified approach.

1.4 Thesis Organization

This thesis is organized in six chapters including this one. Their contents are described briefly as follows:

Chapter 2: provides the necessary background needed to understand this thesis. It gives an overview of ad hoc networks and gives some detailed information on current approaches that address ad hoc networks limited bandwidth

Chapter 3: provides deep description of network coding. It also explains COPE which the foundation of the contribution in this thesis.

Chapter 4: Introduces GBNC as the new coding scheme achieving the desired objectives.

Chapter 5: shows the implementation, experimental results and the performance comparisons of the work.

Chapter 6: summarizes the conclusions and the future work.

1.5 Publications

1. Mohamed Osama and Ahmed Shawish, "Enhanced Network Coding Scheme for Efficient Multicasting in Ad-Hoc Networks," in *Proc. 7th WSEAS European Computing Conference (ECC 2013)*, Dubrovnik, Croatia, June 2013. http://www.wseas.us/e-library/conferences/2013/Dubrovnik/ECC/ECC-64.pdf
2. Mohamed Osama and Ahmed Shawish, "A Novel Network Coding Scheme for Efficient Multicast and Unicast in Ad-Hoc Networks," *International Journal of Computers and Communications*, Vol. 8, P 25-32, January 2014. http://www.naun.org/main/UPress/cc/2014/a082012-121.pdf

CHAPTER 2
SCIENTIFIC BACKGROUND

2.1 Wireless communication

While the deployment and functionality of wired communication networks are constrained by the requirement to setup and establish some infrastructure to support the operation of the network, wireless communication can occur with or without connecting to special infrastructure.

2.1.1 Wireless communication with infrastructure

In wireless communication based upon special infrastructure, such as the GSM or UMTS networks or wireless LANs in infrastructure mode a special dedicated base station or access point is necessary. The nodes participating in the network have to register themselves at this base station or access point. All communication then is realized through these central coordination nodes. A terminal node and a base station or access point are very distinct in their behavior, as illustrated in Fig. 2.1 and Fig. 2.2.

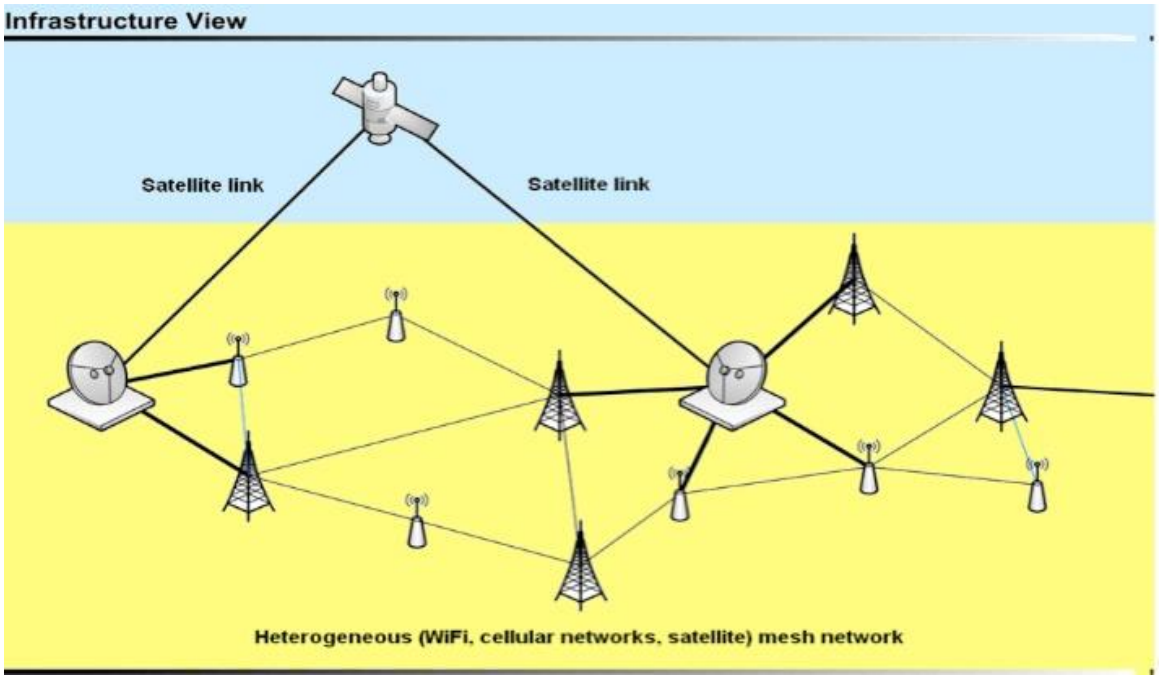

Fig. 2. 1 Cellular mobile communication with infrastructure

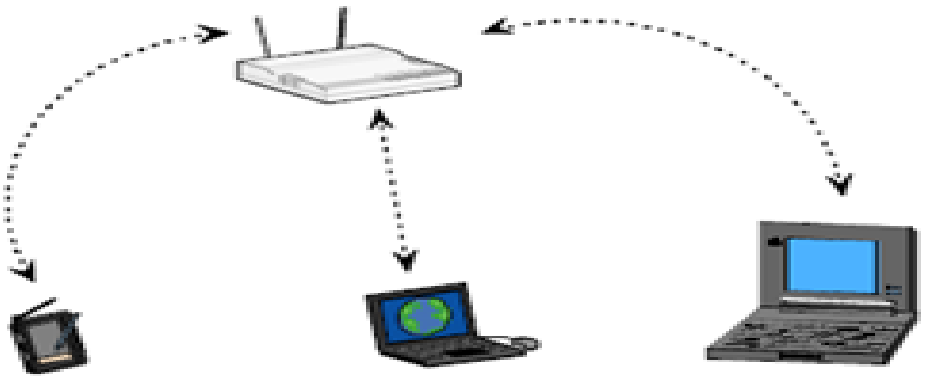

Fig. 2. 2 WLAN in infrastructure mode

2.1.2 Wireless communication without infrastructure

In contrast to the communication with infrastructure, the communication in Ad-hoc networks is organized completely decentralized. There is no central entity regulating or controlling network traffic. All nodes can be at the same time nodes originating and receiving network traffic as well as forwarding traffic for other nodes. Simultaneously they can act as terminal node and as router. All nodes residing sufficiently close to each other to be within radio range can exchange packets without any further measures, as illustrated in Fig. 2.3.

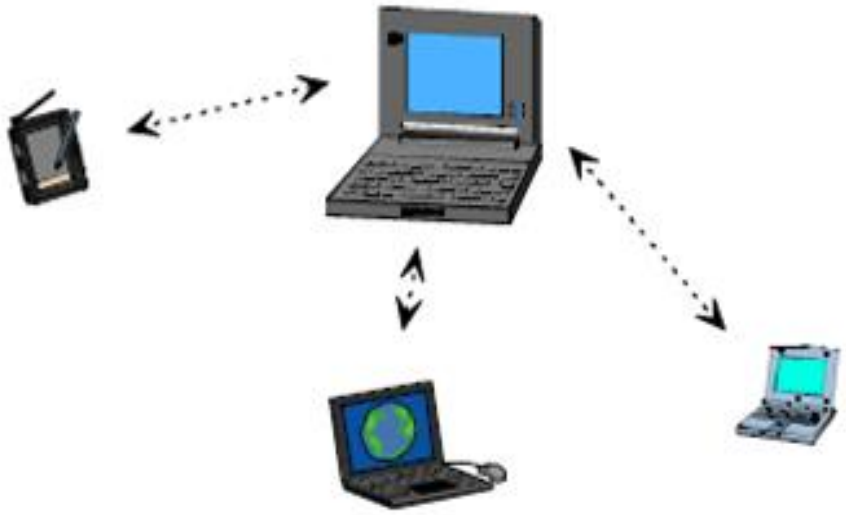

Fig. 2. 3 Direct communication of wireless nodes

To exchange packets with nodes farther away, nodes in between have to forward the packets. In Fig. 2.4 node A can establish a communication with node E as node B,C,D are forwarding the packets exchanged from A to E and vice versa.

Every node thus simultaneously acts as a communication endpoint and as a router for other nodes. Movement of the nodes can lead to changing network topology. The used routing protocol has to be able to react to such changes.

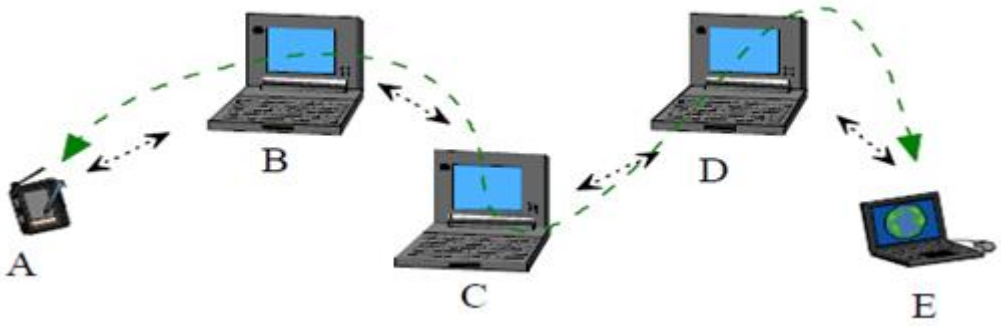

Fig. 2. 4 Exchange of packets by forwarding

2.2 Bringing up an Ad hoc Network

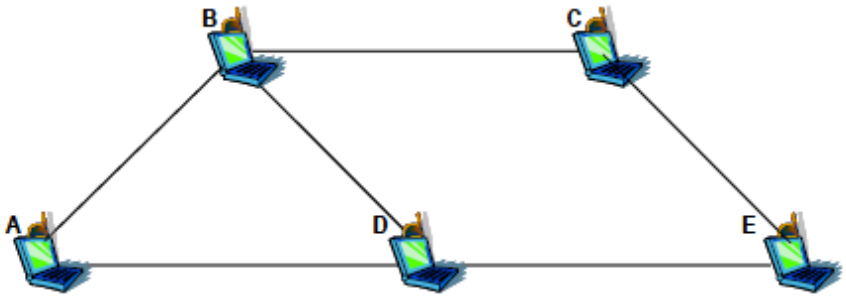

Fig. 2. 5 an example of Ad-hoc network of laptops

1. A typical Ad hoc network begins with at least two nodes broadcasting their presence (beaconing) with their respective address information
2. They may also include their location info if GPS equipped

3. Beaconing messages are control messages. If node A is able to establish a direct communication with node B verified by appropriate control messages between them, they both update their routing tables

4. Third node C joins the network with its beacon signal. Two scenarios are possible:

   (i) A & B both try to determine if single hop communication is feasible

   (ii) Only one of the nodes e.g. B tries to determine if single hop communication is feasible and establishes a connection

5. The distinct topology updates consisting of both address and the route updates are made in three nodes immediately.

   (i) In first scenario, all routes are direct i.e. A->B, B->C, and A->C (Let's assume bi-directional links)

   (ii) In the second scenario, the routes are updated

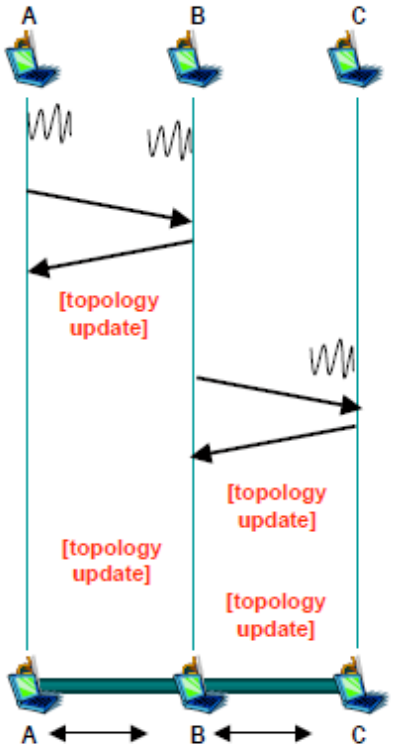

Fig. 2. 6 Topology update

1-First between B & C,

2-Then between B & A,

3-Then between B & C again confirming that A and C both can reach each other via B

2.3 Types

Ad hoc networks can be classified according to their implementation as:

- Wireless MESH networks
- Mobile network: MANET
- Hybrid MESH networks

2.3.1 Wireless MESH networks

- It is a communications network made up with static mesh routers, which have ad-hoc characteristics.
- Mesh clients:
- Laptops, cell phones
- Routers
- Other wireless devices
- It can be implemented with various wireless technologies including 802.11, 802.15, 802.16, cellular technologies or combination of more than one type
- More than 70 routing algorithms

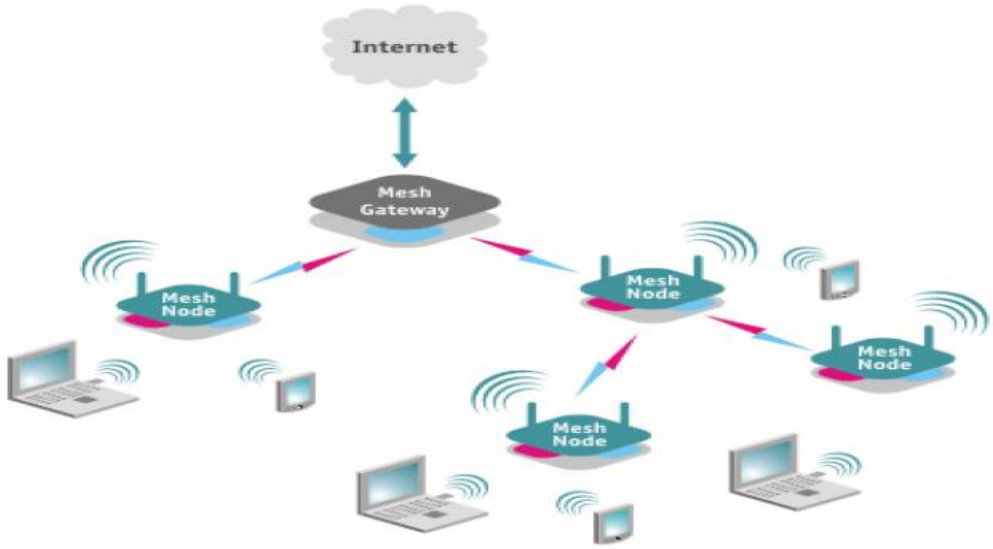

Fig. 2. 7 Wireless Mesh Network

2.3.2 MANET

- It's a self-configuring infrastructure less network of mobile devices connected by wireless links
- Each device is free to move independently in any direction, so it will change its links connection to other devices frequently
- Each node must forward traffic unrelated to its own use, such as router
- Types
- Vehicular Ad Hoc Networks (VANETS)
- Intelligent Vehicular Ad hoc Networks (INVANETS)
- Internet Based Mobile Ad hoc Networks (IMANET)