Route Establishment in Wireless Mesh Networks to Accommadate Network Coding

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***Abstract*—Wireless Mesh Networking (WMN) is a network technology that offers a simple solution to create self organizing wireless networking opportunities between users and the backbone routers.The wireless nature of the network implies a redundancy in network traffic. Network coding offers a way to improve on the network performance, by sharing network resources while at the same time keeping information separate. This paper outlines the concept of practical WMNs together with Network Coding implementation.** [1]

***Index Terms*—network coding; network efficiency; wireless mesh network**

I. Introduction

Wireless networking solutions such as 3G, Wi-Fi and WiMax offer great convenience to the Internet user today, with regards to mobility, ease of installing and hardware interfacing. With a great tendency towards less infrastructure and faster network set-up, wireless ad hoc networking is an attractive solution but comes with added constraints - resource sharing, lower transmission rates, complex and computational burdened routing methods [1], [2]. As a way to improve on the pitfalls faced by ad hoc networks, WMNs offer much of the same advantages with less complex set-up and management effort, but with the cost of less mobility, and can therefore be seen as static wireless ad hoc networks [1]. This characteristic makes WMN a suitable network solution for wireless local area networks (WLANs) typically implemented in office buildings for example. Conventional wireless networks relay traffic from and to each user through a wireless access point (AP) over a single hop distance. This centralised approach is prone to network congestion which in turn affects the network efficiency. Decentralised WMNs establish user-to-user connections by relaying traffic over multiple hops between the users, an easy solution to network congestion with the cost of added ad hoc routing capabilities in the user nodes. In addition to more complex traffic routing management, the existence of a suitable and practical routing protocol is also in question, which gives lead to two arising challenges: (1) Current implemented wireless routing protocol suites used for the IEEE802.11 platform are derived from precedent wired networks, ignoring the wireless nature of WMN nodes and the redundant traffic every broadcast transmission produces [3], and (2) these protocol suites were developed to support bursty and voice data, whereas data traffic showed the greatest increase over the last decade [1], [4]. The remainder of this paper is outlined as follow: Section II will give a brief background on WMNs, as well as Network Coding - a proposed technique to decrease the redundancy of surplus data from wireless broadcast transmissions. Section III describes proposed research and Section IV entails the methodology to follow.

[1]This work was completed at the Telkom-Grintek Centre of Excellence, at the NWU, Potchefstroom

II. Background

A. Wireless Mesh Networks

A WMN is a multi-hop wireless network consisting of a collection of wireless nodes that forms a temporary mesh network when they are within reception range from each other in an ad hoc manner. WMN has the following characteristics [1], [2]: All nodes are equal, there is no main node and any user in the network can be reached by relaying traffic through one or more intermediate nodes. WMNs offer support for ad hoc networking, i.e. the network is capable of self-formation (nodes automatically establish and maintain network connectivity), self-healing and self-organization. There are three main classifications for WMNs [1], [2]:

- Pure ad hoc WMN: Users connect to each other to form a mesh.
- Hybrid WMN: Static router nodes form a routing backbone network, overlaying the mesh of user nodes. The backbone is not connected to external networks.
- Access WMN: Hybrid WMN where the backbone routing network contains gateways to networks external from the WMN, like the Internet.

WMNs offer the following advantages to the end-user:

- Low up-front cost and investment. Network can also be deployed incrementally, as needed.
- Capable of integrating with various external network types, like cellular networks, Wi-Fi, WiMax etc.
- Multiple routes in the mesh topology leads higher fault tolerance and increased robustness.

The main challenge faced by WMNs is the protocols applied in the network stack [5]. MAC and Network layer protocols currently available do not have enough scalability, and as a result the traffic throughput decreases significantly as the

number of nodes or hops increase [2], [6]. The challenge thus is to enhance or re-design these protocols.

B. Network Coding

Network coding is the event of diffusing, mixing or combining network traffic (packets) in order to share network resources and save on the number of transmissions needed to forward information [7]. Ahlswede, Cai, Li and Yeung [8] prove that the multicast capacity of a network is equal to minimum of the maximum flows between the source and any of the individual destinations, but that routing alone is in general not sufficient to achieve this fundamental limit, with regards to several common performance metrics such as throughput, bandwidth usage, scalability, load etc. The aim of network coding is to make this upper throughput limit practically achievable. Network Coding offers great advantages for WMNs [9]: WMN transport network traffic between source and sink nodes, usually at multiple hop distance away from each other. When intermediate nodes mix the traffic passing through them from surrounding neighbour nodes by means of non-trivial coding operations, there exists a gain in the overall network throughput. The number of transmissions needed to forward data packets from source to destination is decreased by a factor depending on the network topology. Further, linear network coding is known to improve network functions such as error correction and traffic security. However, implementing network coding in a practical network raises the following concerns:

- Added computational operations in the nodes' network stack.
- Integration possibilities with routing protocols.
- Cross-layer repercussions due to network coding.

III. Proposed Research

The objective of this research project is to investigate a practical application for Network Coding in WMNs. Review of background literature identified the need of proper network traffic management in order to realise such an implementation. Therefore the research focus will start of by establishing an efficient method to relay constant streaming data traffic through a generic access WMN with a fixed number of user nodes. This also entails constructing a way of measuring network performance to compare results with the current wireless network solutions available.

IV. Methodology

In order to achieve the research objective as set out in Section III, the following methodology will be used:

Routing method determination: Before a session can be established between the source and sink node, there are many factors to consider. In a WMN, there might be one or more alternative routes available between the two communicating nodes, each with different flow patterns through the nodes and coding opportunities on the route. This observation is important in deciding on which routing protocol or method to use.

Timing aspects: Attention should be given to the scheduling and synchronisation between nodes. This is important to manage when nodes can transmit or receive, and also when nodes are performing network coding.

Network information dispersion: Control over a WMN can become very cumbersome if there are no control measurements for the behaviour of nodes. Pro-active information sharing amongst nodes about the overall state of the network is very important, and useful in the case of network coding.

Session set-up: The last step is to actually set-up sessions for the nodes that wish to connect. With the knowledge obtained from the steps described above, a tailor made session can be established, ensuring that the best possible route and routing method is incorporated, while fusing data together from surrounding sessions in order to achieve efficient network communication.

Result comparison: The results obtained from this research can be compared in a two-fold manner:

- Mathematical modelling results compared to simulations and implementation results.
- The results can also be compared with other wireless solutions.

V. Conclusion

This paper presents a way of overcoming some of the constraints faced by wireless networks. Future work entails a mathematical model of the proposed scheme together with simulations in OPNET. Practical implementation is dependent on the availability of a proper test-bed, which is undetermined at this point.

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