Wireless Mesh Networks

{xtypo_sticky} Wireless Mesh Networks: challenges and open issues {/xtypo_sticky}

Wireless meshing has been envisioned as the economically viable networking paradigm to build up broadband and large-scale wireless commodity networks. Several different mesh network architectures have been conceived by both industry and academia; however many issues on the deployment of efficient protocol layers are still open.

Wireless Mesh Network (WMN) is a promising wireless technology for several emerging and commercially interesting applications, e.g., broadband home networking, community and neighborhood networks, coordinated network management, intelligent transportation systems. It is gaining significant attention as a possible way for Internet service providers (ISPs) and other end-users to establish robust and reliable wireless broadband service access at a reasonable cost. WMNs consist of mesh routers and mesh clients as shown in Fig. 1.

Fig. 1. An illustration of wireless mesh network architecture. Mesh routers are static nodes equipped with high processing and memory capabilities, while mesh clients have limited memory, computational power.

In this architecture, while static mesh routers form the wireless backbone, mesh clients access the network through mesh routers as well as directly meshing with each other. Different from traditional wireless networks, WMN is dynamically selforganized and self-configured. In other words, the nodes in the mesh network automatically establish and maintain network connectivity. This feature brings many advantages for the end-users, such as low up-front cost, easy network maintenance, robustness, and reliable service coverage. In addition, with the use of advanced radio technologies, e.g., multiple radio interfaces and smart antennas, network capacity in WMNs is increased significantly. Moreover, the gateway and bridge functionalities in mesh routers enable the integration of wireless mesh networks with various existing wireless networks, such as wireless sensor networks, wireless-fidelity (Wi-Fi), and WiMAX [1]. Consequently, through an integrated wireless mesh network, the end-users can take the advantage of multiple wireless networks.

Starting from this general mesh network vision we investigated, in our researches, several aspects concerning different protocol layers.

MAC layer

The IEEE 802.16 standard [5], promoted by WiMAX (Worldwide Interoperability for Microwave Access) forum (http://www.wimaxforum.org), will be the leading technology for the wireless provisioning of broadband services in wide

area networks. IEEE 802.16 supports mesh connectivity in a distributed manner, and can be implemented in WMNs. The MAC layer is based on time division multiple access (TDMA) to support multiple users. Furthermore, the MAC layer supports two kinds of modes, namely point-to-multipoint (PMP) mode and mesh mode. Almost all the existing works about the IEEE 802.16 are on the PMP mode [6]. In PMP mode, communication is only possible between a base station (BS) and a subscriber station (SS). In mesh mode multihop communication is possible between mesh subscriber stations (M-SSs). A very important factor that influences the performance of mesh networks is the assignment of available network resources. The assignment of resources can be organized in centralized or distributed manner.

In our researches we focused on the Coordinated Distributed Scheduling scheme (CDS). The main idea of the coordinated distributed scheduling is to let nodes calculate the usage of transmission opportunities on the neighborhood scheduling

information. To achieve this goal, nodes will exchange 2-hop neighborhood scheduling information with each other. Since nodes shall run the scheduling algorithm independently, a common algorithm is necessary for each node in the neighborhood to calculate the same schedule. This algorithm must be random and predictable. One feature for the contention in this protocol is the pseudorandom election algorithm based on the transmission schedules of two-hop neighbors.

Nodes in the network are allowed to send their own schedule in a control slot acquired through a pseudo-random algorithm called “Mesh Election function”.

One key factor of this algorithm is that the node persistence for the control slot acquisition is related to a parameter called XmtHoldoffExponent (XHE) [7].

Currently, the standard does not give a rule for XHE setting and users are free to choose this parameter as they like. Our research work starts from the assumption that the correct choosing of XHE values should permit better performance in terms of throughput and average end-to-end data packet delay. In order to verify this assumption, we developed a probabilistic algorithm, based on the buffer data size of each node, that sets XHE values in a dynamic fashion [8].

Our experiments show that, an appropriate configuration of scheduling parameters, such as XmtHoldoffExponent (XHE), may potentially improve the overall scheduling performance in terms of throughput and delay.

Transport layer

To the best of our knowledge, no transport protocol has been introduced specifically for WMNs to date, although several transport protocols have been developed for both wired and wireless networks in the last decade [1].

Based on the TCP drawbacks, several transport layer solutions have been proposed in the literature for wireless networks. All these solutions propose to solve the problems by improving TCP with additional functionalities, modifications, or getting support from lower layers.

It is important to note that all these protocols are based on end-to-end (e2e) rate adjustment and congestion control mechanisms and require a fine-grained end-to-end communication between the source and the destination. Therefore, they may experience significant network inefficiency in WMNs due to the dynamic characteristics of multi-hop wireless environments and e2e delayed and even obsolete receiver rate feedbacks.

To eliminate the drawbacks of end-to-end rate control procedures, hop-by-hop congestion control mechanisms have been studied in several works. Such schemes result in better performance than a corresponding end-to-end scheme by reacting

to network congestion faster than end-to-end mechanisms. Although hop-by-hop strategies improve network throughput significantly, they may not recover from packet losses due to node failures or network disconnections. Hence, in addition

to hop-by-hop approaches, an end-to-end reliability mechanism needs to be integrated in the transport protocol to provide data transport reliability. In this regard, we argue that hop-by-hop rate control schemes are acceptable for WMNs as long as they maximize the utilization of the limited wireless link capacity and provide end-to-end data packet reliability with additional functionalities.

An efficient transport protocol for WMNs should fairly and effectively allocate the limited network resources, e.g., network bandwidth, available buffer capacity, among multiple competing flows, while minimizing the performance overhead it incurs. We argue that an end-to-end congestion and rate control is fundamentally inappropriate for wireless mesh networks, because it suffers from the adverse effects of multi-hop wireless environments, such as variable roundtrip-times (RTT), high BER and radio interferences.

All these discussed challenges and the inherent inefficiencies of the end-to-end approaches in multi-hop wireless environments call for an efficient and responsive transport protocol for WMNs. To address this need, we presented an adaptive and responsive transport protocol (AR-TP) for WMNs [2]. The AR-TP protocol is an adaptive transport protocol based on hop-by-hop congestion control and coarse-grained end-to-end reliability mechanisms, which are designed to achieve high throughput performance and reliable data transmission in WMNs.

In summary, AR-TP protocol makes the following contributions:

It represent a novel fair hop-by-hop rate adaptation mechanism integrated with a coarse-level end-to-end reliability

mechanism, which is specifically tailored according to the challenges of mesh router domains.
Unlike existing hop-by-hop rate control mechanisms, AR-TP releases network congestion using the usual back-pressure mechanism but even introducing a new forward-threshold adaptation one.

It defines the required functionalities and supported capabilities of the mesh router domain, e.g., single buffer for each neighbor, to improve network throughput and fairness. Moreover, compared to the classical end-to-end rate control approaches, we show the network performance improvements of the AR-TP protocol through extensive simulation experiments.

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