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An Improved Channel Assignment Using ROMA in Wireless Mesh Network

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Abstract - In recent years, the wireless mesh network (WMN) attracts the interest of many people as a new broadband Internet access technology. However, increasing throughput is still an open and challenging research issue. One potential solution is to enable transceivers to utilize multiple channels dynamically and Power aware routing in Wireless mesh networks focuses on the crucial issue of extending the network lifetime. which are limited by low capacity batteries and mesh network involves two main challenges first one how to assign channels to radios at each node to minimize interference and how to choose high throughput routing paths in the face of loss links, variable channel conditions and external load. ROMA distributed channel assignment and routing protocol that achieves good multi-hop path performance between every node and one or more designated gateway nodes in a dual-radio network. ROMA assigns non overlapping channels to links along each gateway path to eliminate intra-path interference. ROMA reduces inter-path interference by assigning different channels to paths designed for different gateways whenever possible. The former method aims at minimizing the total power consumption in the network while the latter attempts to decrease the amount of transferred data traffic by utilizing data compression and achieves high throughput.

Keywords: dual-radio, intra-path interference and inter-path interference, link metric, link qualities, external load, multi-hop.

I. INTRODUCTION

Wireless mesh networks comprised of nodes having multiple radios (multi-radio mesh networks) have the potential to perform significantly better than single radio mesh networks. Since every node operates its radio on the same channel in a single-radio mesh network, a forwarding node interferes with the two subsequent nodes along any multi-hop path, drastically reducing the end-to-end throughput. A simple channel Allocation and Routing in Wireless Mesh Network shown fig1.1.

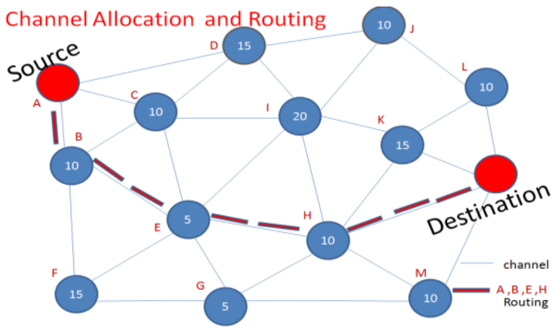

Figure1.1: channel Allocation and Routing in Wireless Mesh Network

A multi-radio mesh can eliminate such intra-path interference if potentially interfering links are operated on non-overlapping Permission to make digital or hard copies of all or part of this work for personal use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, to republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee channels. Another important advantage of multi-radio networks is the ability to use many non-overlapping channels in the same physical region. As a result, there is less inter-path interference among multiple flows in a multi-radio mesh, resulting in higher aggregate throughput. While there has been significant work on multi-radio mesh protocols, realizing the full potential of multi-radio mesh networks in real-world settings has remained a challenging problem. Real-world deployments, especially in urban settings, pose many practical challenges and constraints that affect both the design and performance of a multi-radio protocol. To the best of our knowledge, only a few of protocols have been implemented and even fewer have been evaluated on a tested of reasonable scale.

Each node in a multi-radio network can be equipped with only a few radios. Commodity radios operating in the same frequency band interfere with in close proximity (up to 18 inches). Thus, a multi-radio protocol should perform well on a dual-radio mesh but also be extensible to handle more than two radios per node, should additional orthogonal frequency bands become available. Channels must be assigned carefully to reduce interference in the network. However, when there is only a few radios at each node, it is not feasible to optimize for all paths simultaneously. Fortunately, not all paths are equally important. Most mesh deployments today have a few pre-specified gateway nodes and users care most about achieving high throughput on multi-hop paths from each non-gateway node to a gateway. To take advantage of such traffic patterns, each node should choose routes and channel assignments together to optimize for its gateway paths: when done correctly, one can construct multi-hop gateway paths consisting of high quality links operating on non-overlapping channels and also reduce inter-path interference among paths to different gateways. In this paper, we present the design, implementation and evaluation of ROMA, a distributed routing and channel assignment protocol that achieves high end-to-end performance for gateway paths in a dual-radio mesh.

In ROMA, each gateway chooses a channel sequence, e.g. *c*1, *c*2,to guide other nodes' channel assignment. Specifically, a node ROMA reduces inter-path interference as multiple interfering gateways try to use different channels in their channel sequences. Although proposals that perform joint channel assignment and routing exist, ROMA is the first distributed joint protocol that addresses real world challenges such as lossy and highly variable channel conditions. In particular, ROMA contributes a novel measurement-driven path metric that takes into account link delivery ratios, fluctuations in link quality as well as external load. This path metric allows ROMA to choose multi-hop paths with good performance. The Case for Dual Radios A multi-radio node forwards packets by simultaneously transmitting and receiving on different radios. Although there are many orthogonal channels (3 for 802.11b/g, 13 for 802.11a), it is challenging for a multi-radio node to use different channels from the same frequency band because a node's transmitting radio might interfere with its receiving radio, unless the two radios are separated by a sufficient distance. In order to understand these radio separation constraints, we performed the following experiment with two mesh nodes: We used one node to receive packets sent from a laptop while the other node was simultaneously transmitting packets.

The receiving radio operates on channel 40 (5.2 GHz) and the transmitting radio is on channel 165 (5.825 GHz). We varied the physical distance between the two mesh nodes. Furthermore, we also changed the distance between the laptop and the receiving radio to vary the received signal strength. To prevent the transmitting radio from interfering with a relatively weak received signal, their antennas must be separated by at least 18 inches. Similar results are obtained with a variety of different cards and chipsets. To avoid interference in the same frequency band, one could ensure antenna separation using long pigtails [11], USB cables [13, 30] or Ethernet connections . However, the resulting increase in node size is non-trivial and would significantly limit node placement, especially in indoor settings.As there is no interference among channels in different frequency bands, we can build compact dual-radio nodes by operating a node's two radios on 802.11a and 802.11b/g channels. Any 3-radio compact mesh node is bound to have interference across simultaneously sending and receiving radios because at least two of them have to operate on the same frequency band. To maintain the deployment advantage of compact nodes, we focus on dual-radio mesh networks. Our protocol can also be extended to work with more than two radios at each node.

Wireless Mesh Networks (WMNs) are believed to be a promising technology to offer broadband wireless access to the Internet and to build self-organized networks in places where wired infrastructure is not available or not worthy to deploy A WMN consists of a collection of wireless mesh routers, which are able to self-configure themselves as a backbone and also serve as an access network to offer connectivity to end-users by standard radio interfaces like 802.11. A WMN typically has a two-tier architecture On one hand, mesh routers self-organize themselves to form a wireless backbone, providing large coverage, connectivity, and robustness in the wireless domain. On the other hand, each mesh router is responsible of forwarding traffic on behalf of end-users in its coverage area. A logical separation is maintained between links connecting end-users and links forming the wireless backbone. One or more mesh routers with wired connections will serve as gateways to provide Internet access. While benefiting from large coverage of multi hop wireless connections, WMNs also inherit some scalability problems in terms of throughput, delay, and packet delivery ratio faced by all multi hop wireless networks [9].

In this paper, we look for a more cost-effective solution by exploiting multiple non-overlapping channels using only one transceiver per host. While our goal is to improve network performance, we observe that using multiple channels alone is not very effective. Frequency diversity has to be exploited in concert with spatial and temporal reuse. We propose a protocol named ROMA (Routing over Multi-radio Access Network), a distributed protocol that chooses routing path *and* channel assignment together to optimize the path throughput between every node and a few gateways. We first motivate the basic idea of ROMA before describing its design details. In a mesh network, nodes act as repeaters to transmit data from nearby nodes to distant nodes in the network. Their special utility is in case of providing an in expensive last mile broadband internet connectivity.

In some cases the mesh may be serving as an extension to a wired backbone, thus decreasing the need of a dense physical wire network and hence the cost of maintenance WMNs, though similar in concept, differ on some points with adhoc networks. The nodes in WMNs, despite of being enabled with wireless capacity are stationary in nature or show limited mobility. Thus, topology of WMNs is more or less static. Also, the nature of data flow in a WMN is also the same. For example in an enterprise, traffic mostly consists of internet usage by the nodes or communication between nodes for local file transfers. This provides an opportunity for optimization of WMN's for certain traffic characteristics to improve efficiency. The traffic distribution in a WMN is also in fixed direction, generally to/from a wired/wireless backbone. Introduction of mesh networks also calls for efforts in the direction of increase in network capacity. Usage of mesh networks as an extension to a wired backbone will lead to surge in bandwidth-intensive applications like video-sharing. Usage of multiple channels available in IEEE 802.11a/g standards offers a promising avenue in this regard. the IEEE 802.11b/g standards and IEEE 802.11a standard provide 3 and 12 no overlapped frequency channels, respectively. Utilization of these multiple channels effectively would increase the bandwidth substantially.

II. RELATED WORK

Recently, there are increasing numbers of network applications where their performance is highly dependent on the high data rate. This indicates that higher link capacity is desirable. However, the link capacity is limited in the wireless Mesh networks. Xu *et al.*study the congestion control problem in ad hoc networks. Considering that the objective of maximizing rate allocation can lead to unfairness in rate allocation among the sensor nodes, Hou *et al.* advocate the use of lexicographical maxmin (LMM) rate allocation, and propose a polynomial-time algorithm-serial LP with Parametric Analysis (SLP-PA) to calculate the LMM rate allocation problem. All the works mentioned above have not considered the energy constraint, which is one of the most important criteria in WSNs. On the other hand, Srinivasan *et al.* take into account energy consumption and propose algorithms to the solve the problem for fair data collection under the NUM framework given the network lifetime requirement [27]. Yuen *et al.* propose a fully distributed algorithm to achieve minimum energy data gathering while considering the capacity and interference of the shared medium [14].

Zhu *et al.* study the tradeoff problem between rate allocation and network lifetime, formulating it as a constrained maximization problem, and deriving both a partially distributed algorithm and a fully distributed algorithm to solve it [13]. However, all these works assume synchronous settings, which is difficult to achieve in real wireless networks. Abraham *et al.* introduce a new class of asynchronous distributed algorithms for explicit flow control in an integrated packet network. Kucera *et al.* analyze power and rate control for wireless ad hoc networks with stochastic channels and propose a game-theory based asynchronous distributed algorithm. Bui *et al.* are concerned with joint flow control and distributed scheduling in multi-hop wireless networks shared by multiple users. Based on an interference model, they develop an architecture consisting of a distributed scheduling algorithm in the MAC layer and an asynchronous flow control algorithm in the transport layer. ROMA builds upon a large body of prior work in multi radio mesh protocols. Below, we summarize related work and point out their relationship to ROMA. Centralized channel assignment solutions aim to find the best combination of routes, channel assignment and transmission schedules given the network topology on *all* channels and the traffic pattern. Most centralized optimizations [27, 25, 24,] are evaluated in simulations and lack practical solutions for coordinating topology measurement and disseminating channel assignments.

The channel assignment algorithm in [30] always takes into account of external load estimated using received packets. Distributed channel assignment: Most practical multi-radio deployments choose not to perform sophisticated channel assignment but use identical channels on all nodes [16, 13, 8]. Assigning channels dynamically in a distributed fashion is a hard problem and only two known protocols do so [20, 32]. In [20], the authors propose a distributed channel assignment protocol that relies on a common channel across the network to ensure connectivity. Each node runs the distributed assignment protocol to select a channel for its other radio. The assignment prefers channels that are least used by a node’s interfering neighbors.In comparison, ROMA does not require a common channel and can use channels more efficiently to eliminate intra-path interference and improve aggregate throughput.

Routes consisting of highly lossy and fluctuating links are bound to perform poorly and Hyacinth cannot adapt to changing channel conditions other than node failures. Furthermore, Hyacinth’s join/leave protocol for spanning tree construction can be fragile in lossy environments as it requires reliable delivery of protocol messages and accurate detection of node failures. By contrast, ROMA explicitly incorporates link loss, loss variations and external traffic load in the link metric and can quickly adapt to changing channel conditions. Route selection: WECTT and SIM are two path metrics that help routing protocols preferentially choose routes with less intra-path interference. ROMA uses the SIM metric for choosing paths and extends it to take into account link variations and external load. While our modification of the ETT metric is similar in spirit to the mETX metric, there exist subtle differences. The rationale for modeling the worst-case scenario follows from ROMA’s goal of choosing routes where each link delivers good and predictable performance. In addition, computing mETX requires bit-level loss information from all corrupted packets. However, most packet losses do not result in any (corrupted) packet reception in our tested.

III. PROBLEM DESCRIPTIONS

The basic problem is given a dual-radio mesh network, how does a distributed protocol assign channels and select routes that achieve high end-to-end performance?

- The channel assignment challenges in Multi-radio networks achieve high performance by assigning non overlapping channels to eliminate harmful intra-path interference and reduce inter-path interference whenever possible.
- A single multi-hop path, one can easily assign channels to eliminate intra-path interference each forwarder uses two distinct channels to communicate with its previous and next hop neighbor.
- Channel assignment becomes much more challenging if it is to reduce interference for all paths under arbitrary traffic patterns, since each node has only a few radios (two in our case), far fewer than the number of available non-overlapping channels.

Assigning a common channel to all nodes maximizes network connectivity but causes half of all links to operate on the same channel (the common channel), resulting in increased intra and inter-path interference. Centralized algorithms without the use of a common channel cannot adapt robustly to cope with network changes. For a mesh network that provides Internet access to many clients, we can exploit the predominant traffic pattern to optimize the performance of gateway paths only. To do so, a multi radio protocol should jointly choose gateway paths and channel assignments to ensure that each gateway path consists of high quality links operating on distinct channels and that paths to different gateways use different available channels whenever possible.

Routing challenges: Since intra-path interference is unlikely with careful channel assignment, the throughput of a multi-hop path in multi-radio networks is limited by its worst performing link. It is difficult to estimate link quality not only are links lossy, but loss rates also vary across different timescales.

IV. LINK MESUREMENT AND ROUTE PROPAGATION

Select the most promising neighbor for investigation every *Tinvs*.

Step1:for all x of my potential neighbors do
Step2:for $c \in x$'s home channels do
Step3:if $c \notin$ my channel assignments
Step4:Then$m \leftarrow$ metric of link between me and x on channel $c$if m does not exist
Step5:Then $m \leftarrow min$ //assume the best link metric
Else //if link is measured before, weigh its metric by age
Step6: $m \leftarrow m + (min - m) * 0.1$
Step7: end if
Step8:Estimate my path metric via x using x's gateway path metric and m
Step9:Remember (x, c) corresponding to the best path metric
Step10:end if
Step11:end for
Step12:if the best estimated path metric is less than a threshold of my current gateway metric then investigate the link to x on channel c.
Step13:end if

As the underlying network topology changes, a node may need to use different home channels for its best gateway path. To converge to the best possible channel assignment and gateway path, a node performs temporary channel switches to explore alternative gateway paths efficiently. The goal of temporary channel switch is to investigate the quality of a specific link on a foreign channel with the hope that it will yield a better gateway path than the current one. To maximize the chances that a temporary switch finds a better path, a node chooses the most "promising" link among all potential neighbors for investigation. Two types of information are needed in order to choose the most promising link: the current home channels of potential neighbors and their gateway path metrics. ROMA employs network-wide gossip to inform each node of its potential neighbors' channel

Assignments as well as their gateway path metrics. Algorithm1 gives the pseudo-code for finding the most promising link for investigation. Every *Tinvs* seconds, a node estimates the link delivery ratio to a neighbor (x) on one of x's home Channels. If the node has never investigated that link before, it optimistically assumes the best link metric. Otherwise, it uses the existing link metric discounted by the age of that information. The node then uses the estimated link metric and x's gateway path metric to estimate the metric of the potential gateway path via x. The most promising link for investigation is one with the best estimated gateway path metric. If the estimated path metric is less than a threshold of the node's current gateway path, the node starts the actual investigation by switching to the foreign channel.

V. IMPLEMENTATION

We have implemented ROMA using the Click modular router toolkit [21] as a Linux kernel module. Our implementation re-uses part of the software infrastructure originally developed for the Src routing protocol. The kernel module directly invokes the functions exported by the wireless driver to change channels. Upon receiving the command to change channel, the driver waits until its current transmit queue is drained by the radio hardware before switching to the new channel. ROMA uses source routing when forwarding data traffic. The sender specifies the sequence of forwarders and the channels to be used, and intermediate nodes in the path forward packets based on the specified source route.

VI. PERFORMANCE EVALUATION

This section demonstrates the following points about the performance and behavior of ROMA

1. ROMA eliminates intra-path interference and the throughput of multi-hop gateway paths is comparable to that of single hop paths.
2. ROMA achieves good aggregate throughput in the presence of many active flows and multiple gateways by utilizing many non-overlapping channels within the same physical area.
3. Incorporating link variation and external load in the path metric helps ROMA choose better multi-hop routing paths
4. ROMA chooses stable channel assignments and gateway paths while remaining adaptive to changes in the underlying topology. By preserving cross-links among paths to the same gateway radio, a node can sometimes change its gateway path without changing channel assignment

In the simplified case, ROMA aims to assign channels to eliminate intra-path interference for all routing paths to a single gateway radios. In the single gateway radio case, inter-path interference is not an issue since competing flows contends for the same gateway resource. In the multiple gateway case, ROMA also aims to reduce inter-path interference for paths destined to different gateway radios performance Evolution Calculating link metric the most popular link metric today is ETX and its extension ETT. Both metrics explicitly measure the delivery ratio of a link and ETT is a scaled version of ETX to adjust for different link level transmission rates. In our initial implementation of ROMA, we found that using ETT often leads to suboptimal routing paths. Our improved link metric incorporates two additional factors to estimate the quality of a link: link variation and external load. As a result, a path that should perform well judging from its individual links' ETTs often has low actual throughput because the delivery ratio of some link along the path happens to incur higher than average loss rate. We modify the way standard ETT is calculated to account for delivery ratio variations. In ROMA, each node keeps track of two variables, *pa* and *pv*, which are exponentially weighted moving averages (EWMA) of the average and mean deviation of the link delivery ratio. Specifically, let *p* be the latest measurement of the delivery ratio, *pa* and *pv* are update as follows:

$$pa = pa + g \cdot (p - pa) \quad \ldots\ldots\ldots (1)$$

$$pv = pv + g \cdot (|p - pa| - pv) \quad \ldots\ldots\ldots(2)$$

To calculate measurement of the delivery ratio using above equation. If the delivery ratio of a link has high variations as indicated by a large *pv*, that link is more likely to exhibit much lower than average Delivery ratio during the actual data transmissions.

The throughput of a link is reduced by competing traffic on the same channel. In a multi-radio mesh, a node can potentially find an alternative route on different channels with less competition. ROMA's path metric (M) extends the SIM metric to take into account external load and is calculated as follows:

$$M = (1 - \beta) \cdot S + \beta \cdot T \quad \ldots\ldots\ldots (3)$$

$$\text{where } S = \text{X}i \in pathETT(i)$$

$$T = maxs\text{X}i \in SegsETT(i) \cdot (1 + L(i)) \ldots\ldots (4)$$

The extended SIM metric (*M*) is a linear combination of path overhead (*S*) and performance (*T*) with parameter *β*balancing the tradeoffs between them. The path overhead *S*is approximated by the sum of expected transmission time along the path. The path performance (*T*) is characterized by the estimated service interval of the bottleneck path segment and a smaller *T* corresponds to better performance. A path segment consists of one or more links that interfere with each other on overlapping channels. In the common case, links operate on distinct channels along the gateway path and thus form path segments of length one. The original SIM metric estimates the service interval of the bottleneck path segment using the sum of ETT along that segment [13]. In ROMA, the estimated service interval of a link is its ETT weighted by the observed external loaded. $ETT \cdot (1 + L)$. When the external load increases from zero to near 1, the estimated service interval doubles. We find that this simple approach works well in practice.

In Deployed mesh access networks, each node acts as both mesh forwarder and an AP for unmodified single-radio clients. It is desirable for the link between a client and its associated AP to follow the corresponding gateway channel sequence to avoid intra-path interference. If other words, if a mesh node operates on channels ($a1$, $b1$) and uses channel $a1$for its gateway path, it should make its clients preferentially associate itself on channel $b1$ instead of $a1$.Link measurement and route propagation Once a node has found its best gateway path, it switches to the assigned channels, called home channels, according to the gateway's sequence. Each node continuously monitors its neighboring links' conditions on the home channels and propagates its current gateway path and path metric to keep other nodes up dated. Link quality measurement: A node can directly communicate with a subset of all its potential neighbors (i.e. actual neighbors) whose home channels overlap with the node's own. The previous hop of a node's gateway path is one such actual neighbor. Each node snoops the medium to measure external load and periodically broadcasts probe packets every *Tbcast* seconds from all radio interfaces to measure the delivery ratio of links to its actual neighbors. We have noticed that, for some links in our tested, the loss rate observed on a long burst of transmissions is much higher than that of a very short burst and stabilizes when the burst length exceeds 20 packets. As a result, broadcasting probes one at a time causes a node to dramatically over-estimate the actual delivery ratio during data traffic forwarding.

We find that using a burst size of 20 packets results in robust delivery ratio measurements. Route propagation: Each node periodically announces its current channel assignment, gateway path and the corresponding gateway sequence on its home channels. The gateway path consists of a series of forwarding nodes, their channel assignments as well as the link metrics (in terms of ETT and external load) between successive forwarders. A gateway node announces a path of length zero to indicate its gateway status. A node without any gateway path announces a path length of ∞ on the default 802.11a and802.11b/g channels. A node processes received advertisements from all interfaces and stores extracted node and link information in a partial local link table [15, 7]. The link table contains the list of known nodes with their corresponding home channels as well as the link metrics between them. In order to distinguish new information from old ones, each node or link entry in a route announcement is associated an increasing sequence number generated by the originating node. A node continuously updates the path metric of its current gateway path. Furthermore, if a node finds a better gateway path in its link table that does not require it to change home channels, it immediately switches to the new route.

VII. CONCLUSIONS

Designing a high-performance multi-radio protocol faces many practical constraints and challenges (small node size, highly fluctuating link qualities, external load). ROMA is a distributed protocol that performs routing and channel assignment to achieve high end-to-end performance in a dual radio mesh by eliminating intra-path interference and reducing inter-path interference. ROMA finds higher performance multi-hop paths by leveraging a new path metric that incorporates link variations and external load. ROMA also adapts well to network topology changes while choosing stable routing paths. In addition, we proposed an interference and congestion aware routing algorithm in the hybrid network, which balances the channel usage in the network, thereby increasing the network throughput.

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