

A Demonstration of a Cross-Layer Cooperative Routing-MAC scheme in Multi-hop Ad-Hoc Networks

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Abstract—Cooperative communication fully leverages the broadcast nature of the wireless channel and spatial diversity, thereby achieving tremendous improvements in system capacity and delay. A cross-layer implementation approach has been pursued in this demonstration, in order to confirm the viability and efficacy of cooperation at the MAC layer, in conjunction with the routing layer, in multi-hop ad-hoc networks. In the cooperative MAC protocol [1], a station would use a neighboring helper station for MAC layer forwarding, if the two-hop relaying yields to a better performance than a direct single-hop transmission. In this cross layer scheme, the DSDV routing protocol [2] defines a multihop path from the source to the destination, while the cooperative MAC scheme, eventually selects two hop forwarding for each routing layer hop, in order to boost the performance of the routing protocol. The Cooperative MAC scheme has been implemented in the MadWiFi [3] driver, while the DSDV routing protocol has been implemented in the Click modular router [4]. In the demo, a video clip is streamed from a server to a remote client, where the received video is played out in real time. The basic route is discovered by the DSDV routing protocol that runs on every station. The underlying MAC implementation would dynamically alternate between IEEE 802.11g and the cooperative MAC protocol, for each route hop. In the multi-hop, ad-hoc network, the cooperative cross-layer scheme delivers a smooth user experience while the video playout over the legacy IEEE 802.11g has noticeable freezes and frequent distortions. The demo verifies the extensibility of the cooperative MAC protocol into multi-hop ad-hoc networks, where in conjunction with the routing protocol, can achieve superior performance, compared to the legacy IEEE 802.11g.

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I. THE COOPERATIVE MAC PROTOCOL

Following the philosophy of cooperation, we have implemented a Cooperative MAC protocol for ad-hoc networks [1]. In this protocol a station would resort to a neighboring helper station for MAC layer forwarding, if the two-hop

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relaying yields a better collective performance than a direct transmission.

A mobile station that experiences a bad channel tends to transmit at a low rate in order to decrease the bit error rate (BER). However It can use a relay that is located in its communication range in order to improve the network performance. The relay, called helper, is selected in a way that it can sustain high data rate between itself and both the source and the destination. In this manner, the direct transmission at a low rate is replaced by the two-hop forwarding at high rates(i.e., from the transmitter to the helper and from the helper to the receiver), thereby boosting the overall performance. Every station maintains information about its candidate helpers in a table called *CoopTable*. Corresponding to a particular helper station, each row in the *CoopTable* stores the MAC address of the helper and the transmission rates that this helper could provide for the two hop transmission (i.e., from the transmitter to the helper, and from the helper to the intended destination).

II. IMPLEMENTATION OF THE COOPERATIVE MAC PROTOCOL IN CONJUNCTION WITH DSDV ROUTING

The DSDV routing protocol [2] defines a multihop path from the a source station to a destination station, while the cooperative MAC scheme, eventually selects two-hop forwarding for each routing layer hop, in order to boost the performance of the routing protocol. The Cooperative MAC scheme has been implemented in the MadWiFi [3] driver, while the DSDV routing protocol has been implemented in the Click modular router [4]. In the demo, a video clip is streamed from a server to a remote client, where the received video is played out in real time. The basic route is discovered by the DSDV routing protocol that runs on every station. The underlying MAC implementation would dynamically alternate between IEEE 802.11g and the cooperative MAC protocol, for each hop of the route.

The implementation of the cooperative MAC protocol in this demo is based on MadWiFi, which is an open source IEEE 802.11a/b/g Linux driver for the Atheros chipset. Before sending a packet to the next-hop, the transmitter attempts to

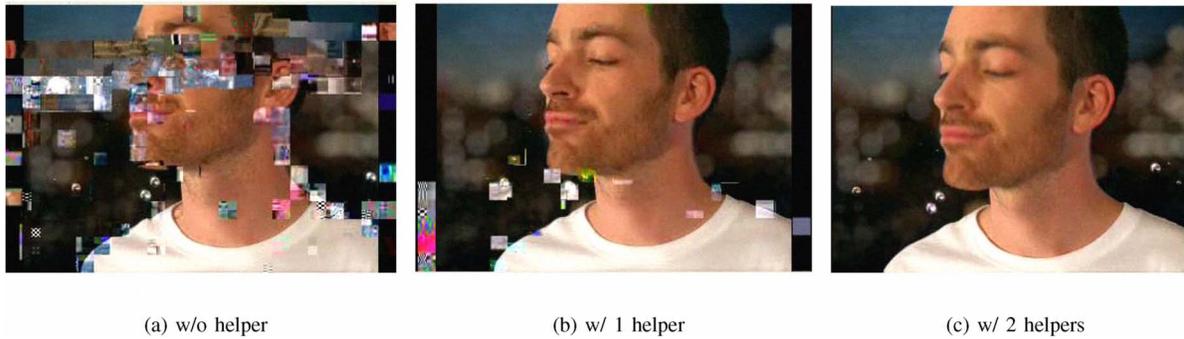


Fig. 1. Demo results

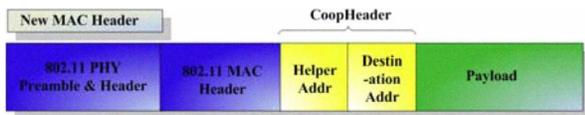


Fig. 2. A new MAC Header

choose an optimum helper as a relay. If a helper is selected for a particular routing layer hop (i.e., from the transmitter to the next-hop node), a new new field is inserted in the MAC header of the packet, between the original MAC header and the payload, which we called *CoopHeader*. The new MAC header is shown in Fig. 2. The *CoopHeader* keeps information about the intended destination for the particular hope on the route, and the selected helper for the ongoing transmission. Depending on the specific role a station undertakes, different functionalities will be invoked, as it is summarized in Table I.

TABLE I
SUMMARY OF IMPLEMENTED FUNCTIONALITIES

Role	New Functionality
<i>Source</i>	Helper selection, based upon <i>CoopTable</i>
<i>Helper</i>	Cooperative packet relay (removing <i>CoopHeader</i>)
<i>for all</i>	<i>hello</i> packet broadcast

In a real environment, every station could be considered as a candidate helper by its neighboring stations. We have implemented a broadcasting scheme using a *hello* packet in each station. The *hello* packet is generated directly by the MAC layer and is broadcasted on a periodic basis, and it indicates the sustainable rates between the the particular station and its neighbors. A mobile station updates its *CoopTable* based upon the received *Hello* messages, in order to be aware of candidate helpers, and revokes timely an enlisted helper once the helper becomes inactive.

III. DEMONSTRATION OF VIDEO STREAMING OVER A MULTI-HOP NETWORK

A. Demo Configuration

The demo consists of 5 laptops. The basic configuration of the laptops is outlined in Table II.

TABLE II
BASIC CONFIGURATION OF MOBILE STATIONS

Model	Lenovo 7732-8AU
CPU / Memory	Intel Pentium(R) Dual CPU, 1.60 Ghz / 1 GB
Operating system	Fedora Core 5, kernel ver 2.6.16
802.11 NIC	NL-5354CB+ Aries2(f), PCMCIA
802.11 Chipset	Atheros AR5004+

The topology of the testbed is illustrated in Fig. 3. One of the laptops is the source, one is the relay router, one is the destination, and the other two are candidate helpers. In order to emulate a multi-hop topology in the Lab environment, we introduced a MAC filter in the driver level, to guarantee that a node can only hear other nodes that belong to the same BSS. The two-hop rates that the two helpers can sustain are listed in Table III.

TABLE III
CANDIDATE HELPER IN EACH BSS

Name	First Hop Rate	Second Hop Rate
Helper 1 in BSS1	24 Mbps	24 Mbps
Helper 2 in BSS2	11 Mbps	11 Mbps

B. Demo Description

The transmission of a video clip is considered in the described testbed. A VLC server at the source station streams a commercial video clip constantly, while the VLC client at the destination receives the video and plays it in real time. The demo consists of four sequential phases, as outlined in Table IV. The four phases run in a cyclic way. The transition from one phase to the other is controlled by scripts running at each helper in order to set their state to "on" or "off".

As described in Table IV, when the video is transmitted over the traditional routing protocol, the user perception is poor, as noticeable freezes and distortions occur frequently. Meanwhile, the video is smooth and artifact-free, as it is received when the cooperative MAC scheme is active within each network route. The intermediate stage where cooperation is used in some of the hops (phase 1 and 2) shows that cooperation can improve the performance of the transmission

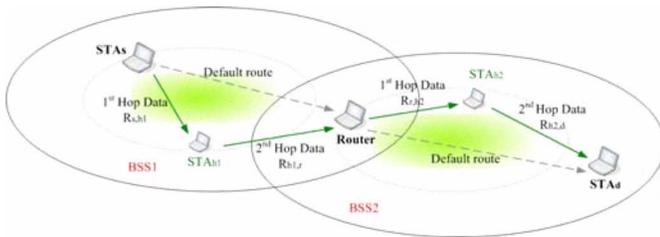


Fig. 3. Demo setup.

TABLE IV
FOUR PHASES IN THE DEMONSTRATION

Phase 1	Helper 1 is active, helper 2 is inactive. Cooperation is active in parts of the network route. The video quality is good at the destination.
Phase 2	Helper 1 is inactive, helper 2 is active. Cooperation is active in parts of the network route. The video quality is good at the destination.
Phase 3	Both the helpers are active. Cooperation is active in every hop of the network route. The video quality is superior at the destination.
Phase 4	None of the helpers are active. No cooperation occurs in the multi-hop transmission. The quality of the video is poor.

even when it is partially used in the network. The comparison of the three figures is typical and it reveals the substantial improvement in the video quality that the Cooperative scheme can deliver in large scale ad-hoc networks.

C. A Graphical User Interface: Coop-DSDV GUI

To simplify user participation, we developed a *Coop-DSDV GUI*, based on Java SDK 1.4 for Linux. *Coop-DSDV GUI* communicates directly with the driver, and obtains the corresponding state information and the communication parameters, e.g., the MAC address of every station or the transmission rate that the station is using. At the transmitter, the *Coop-DSDV GUI* displays the information of the helper that is being used (i.e., the MAC address and the rates that the helper can sustain). At the helpers, the *Coop-DSDV GUI* shows the state (on/off) of the helper and the rates that it is providing for the two-hop transmission. The GUI allows users to configure the sustainable rates of the helpers, and it also provides a real time emulation of the data flow which indicates the current transmission path from the host station to the final destination. As an example, a snapshot of the *Coop-DSDV GUI* at the source station is shown in Fig. 4.

D. Procedural Details

The demo needs a table to place the 5 laptop computers. It needs power support for all the five laptops. The setup time is 15 minutes.

IV. CONCLUSION

In this demonstration, we have implemented a cooperative cross-layer scheme between MAC and routing layer. The demo verifies the extensibility of the cooperative MAC protocol into multi-hop ad-hoc networks, where in conjunction with the

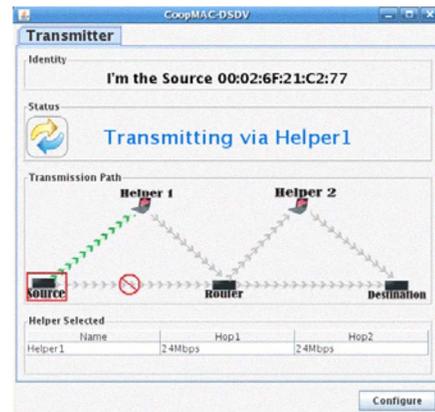


Fig. 4. The source's GUI

routing protocol can achieve superior performance, compared to the legacy IEEE 802.11g.

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