CARMEN: Resource Management and Abstraction in Wireless Heterogeneous Mesh Networks*

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ABSTRACT

Even though current mesh networks are mostly WiFi-based, future networks are expected to be highly heterogeneous. Motivated by this expectation, CARMEN (CARrier grade MEsh Networks) project focuses on developing a heterogeneous mesh backhaul to provide carrier-grade (voice, video and data) services. This demo presents resource management and abstraction in CARMEN architecture, which allow meeting the challenges of heterogeneous radio access.

Categories and Subject Descriptors

C.2.1 [**Network Architecture and Design**]: Wireless communication

General Terms

Design, Management, Measurement

Keywords

Heterogeneous, wireless mesh, resource abstraction

1. INTRODUCTION

Wireless mesh networks (WMNs) have high potential for improving wireless coverage as seen by the number of community mesh networks worldwide. Although current deployments are mostly WiFi-based, future networks are expected to be highly heterogeneous. Such a future is unavoidable due to the high diversity in available radio access technologies, which offer different performance and cost trends and hence, tailor to different needs. The main goal of the CARMEN project [1] is to develop a heterogeneous mesh backhaul network for carrier-grade communication.

The main challenge in heterogeneous networks is the integration complexity of different radio technologies. To address this, CARMEN introduces an abstraction layer between the subnet and the network layers to translate technology specific issues into a common set of events and commands to be used by upper layers (e.g., self-configuration, routing and mobility functions). In addition, CARMEN provides abstraction of heterogeneous resources by turning *physical* links of an access technology to *abstract* links. Specifically, the self-configuration function discovers and groups links that share the same *capacity*, i.e., that may interfere with each other, within the same *link group*. The available capacity of the link group is abstracted based on the cost of the specific radio access technology, which is in turn used by routing and resource reservation. The objective of this demo is to show the operation of link groups in the CARMEN architecture, supporting abstraction and management of heterogeneous resources.

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2. CARMEN RESOURCE MANAGEMENT

To provide carrier-grade services over different technologies, a common set of primitives, and a *technology-agnostic* way of managing resources are needed. To this end, CARMEN defines the architecture in Fig. 1, with two key components: (1) The Interface Management Function (IMF), an extension of IEEE 802.21, that defines a new set of common primitives to be used by upper layers, e.g., self-configuration. (2) The technology-specific MAC adapters that provide resource abstraction and management. They interface with the packet queuing system for traffic handling and comprise of link group management and monitoring management (MoMa).

Link Group Management and Traffic Handling

Resource management within a link group is administered by the Link Group Manager (LGM), which computes *abstract* link costs that represent the resources consumed by a transmission over a link due to e.g., the current modulation [2]. Given the link cost for a flow i, c_i, and the total capacity C of the link group, the bandwidth assignment to each flow i should respect the following inequality: $\sum_i c_i r_i \leq C$. LGM provides this information to the routing function, which computes optimal routes based on linear programming.

Resource reservations are also handled by the LGM, which configures the MAC parameters to meet the desired bandwidth and delay requirements. For instance, in IEEE 802.11e-based CSMA, LGM tunes the EDCA parameters of each output queue and broadcasts the new configuration to all nodes in its link group.

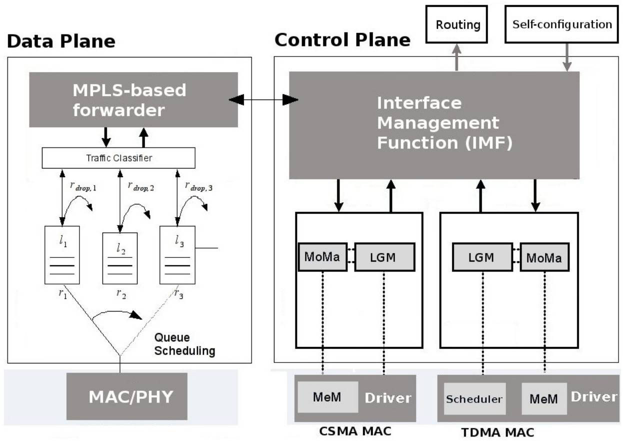

Figure 1: Data and control planes in CARMEN. In the control plane, IMF provides message dispatching between upper and lower layers. MAC adapters interface with the drivers to perform link group and monitoring management.

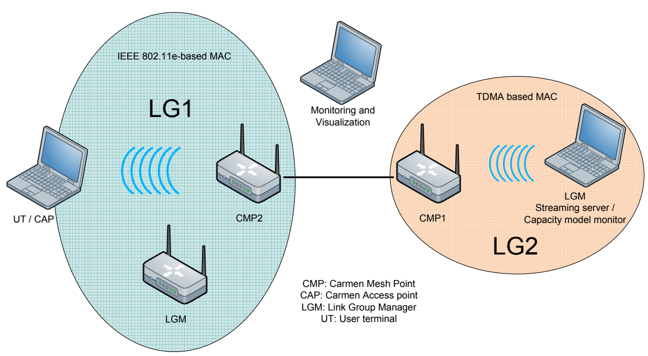

Figure 2: Demo network topology.

Measurement and Monitoring

For managing wireless resources (e.g., computing current link costs), a number of statistics is recorded at each node, e.g., Signal to Noise Ratio (SNR), channel utilization. Based on these measurements, MoMa function generates link reports, which might trigger changes by self-configuration and routing. The basic algorithm used by MoMa is as follows: (1) After T_1 seconds of silence from a neighbor, the link is marked as *Going Down*. (2) If nothing is heard for an additional T_2 seconds, the link is marked as *Down*.

3. DEMO SCENARIO

To show how CARMEN abstracts the underlying heterogeneity in the network, we use the scenario depicted in Fig. 2, where one CARMEN Access Point (CAP) acts as a standard IEEE 802.11 client, several mesh nodes and laptops act as CARMEN Mesh Points (CMP), and one additional laptop performs monitoring and visualization of events.

Link Group Configuration

In our example, the network is already configured to have 2 link groups, one with a TDMA-based MAC (over WiFi) and one with IEEE 802.11e-based CSMA MAC. All nodes use single radios to reduce the impact of intra-node interference. In Fig. 2, CMP1 and CMP3 are wired and act as a single node with dual radios supporting multiple technologies. These two link groups are shown using the output from the monitoring node.

The TDMA-based MAC is a custom token-based protocol, where the LGM computes a schedule based on traffic requirements and passes tokens granting the right to send to each node in its link group. The CSMA-based MAC builds on top of the standard EDCA using the ad-hoc mode. Although all nodes can potentially act as the LGM, a voting mechanism is used to elect one. This node then broadcasts EDCA parameters.

Traffic Handling within Heterogeneous Link Groups

Traffic handling will be shown via different resource allocations in the two link groups. The costs associated with using different links will be displayed using flow tables, which show the total bandwidth in each link group, the available bandwidth for and the actual bandwidth used by each flow, and the cost of the link.

To show the effect of resource allocation, we will first stream video to the client, which is associated to the CAP 2 hops away from the video server (see Fig. 2), without resource allocation. In this case the video will be treated like Best-Effort traffic. Even though there is no contention in the network, viewing problems might occur due to streaming through 2 hops and wireless interference. This will be our baseline operation. Next, we will start background flows in both link groups, and show that video performance severely degrades.

Next, we will perform resource allocation by LGMs, adjusting the MAC parameters at each link group. Flow tables will show the current resource allocations, where the allocation parameters are set differently for each technology. Hence, although the underlying technologies are different, their specifics are hidden away from the upper layers. Next, we start the video and the background traffic again and confirm that the video is not as severely affected.

4. CONCLUSION

Heterogeneous wireless mesh networks will become an integral part of carrier-grade wireless networking. Resource management and abstraction play a key role in utilizing different radio access technologies within the same infrastructure. To the best of our knowledge, this is the first demo that shows how to expose the costs and capabilities of different radio access technologies to the upper layers, namely, self-configuration and routing.

5. REFERENCES

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