Poster Abstract: SCORPION: A Heterogeneous Wireless Networking Testbed

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I. Introduction

During the last decade, the success and popularity of wireless standards such as IEEE 802.11 have drawn the attention of the research community to wireless networks. A great amount of effort has been invested into research in this area, most of which relies heavily on simulation and analysis techniques. However, simulations do not precisely control hardware interrupts, packet timing and real physical and MAC layer behaviors. As a result, simulation results need to be validated by real implementations, which is evident by the change in focus of research activities increasingly moving towards real implementations, including the deployment of testbeds as a main tool to analyze network protocol functionality. Under this context, we present an overview of *SCORPION* (Santa Cruz mObile Radio Platform for Indoor and Outdoor Networks), a heterogeneous wireless networking testbed that includes a variety of nodes ranging from ground vehicles to autonomous aerial vehicles. The purpose of SCORPION to is to deploy and investigate nascent networking protocols using a variety of mobile platforms utilizing structured as well as unstructured mobility patterns.

I.A. Goal

Node diversity in terms of mobility and capabilities (e.g., processing, storage, and communication) makes the SCORPION testbed well-suited for testing and evaluating a variety of wireless network protocols, including multi-radio, multi-channel medium access control, multi-hop wireless ad-hoc routing, as well as disruption-tolerant routing and message delivery protocols for networks with varying connectivity.

In its current implementation, SCORPION includes nodes outfitted with three different types of *autonomous* vehicles, namely: (1) iRobot Create ground robots [7], (2) remote controlled airplanes equipped with Paparazzi autopilots [11], and (3) self-stabalizing remote-controlled helicopters [4].

Additionally, two non-autonomous mobile nodes complement the testbed. The first is a briefcase node that will be carried by people in order to mimic human mobility patterns. The second is a bus node which will provide structured mobillity patterns for the testbed. The bus nodes will be deployed in the UC Santa Cruz campus bus

The testbed currently has four airplane nodes, four helicopter nodes, 20 iRobot Create nodes, 40 briefcase nodes, and 40 bus nodes. The iRobot Create nodes are equipped to carry briefcase nodes, allowing for a total of 88 nodes to be active at any one time during testbed operation. It should be stressed that each node has the capability to communicate with every other node in the testbed (bus to bus, bus to airplane, helicopter to briefcase, etc.).

The varied mobility patterns exhibited by these nodes allow for unique and innovative ways to test network protocols for current as well as next-generation network applications. SCORPION's management suite facilitates updating system and protocol software running on the nodes as well as monitoring the current status of nodes. Conditions that the management tool reports include whether the node is up or down, what versions of the operating system, software and protocols are running. The management tool also includes scheduling capabilities for running multiple protocols during each deployment.

I.B. Related Work

The recent proliferation of efforts aimed at building wireless network testbeds is clear evidence that testing and evaluating wireless network protocols under realistic conditions is critical. One notable example is Rutgers University's ORBIT project which focuses on creating repeatable experiments in a wireless testbed setting [6].

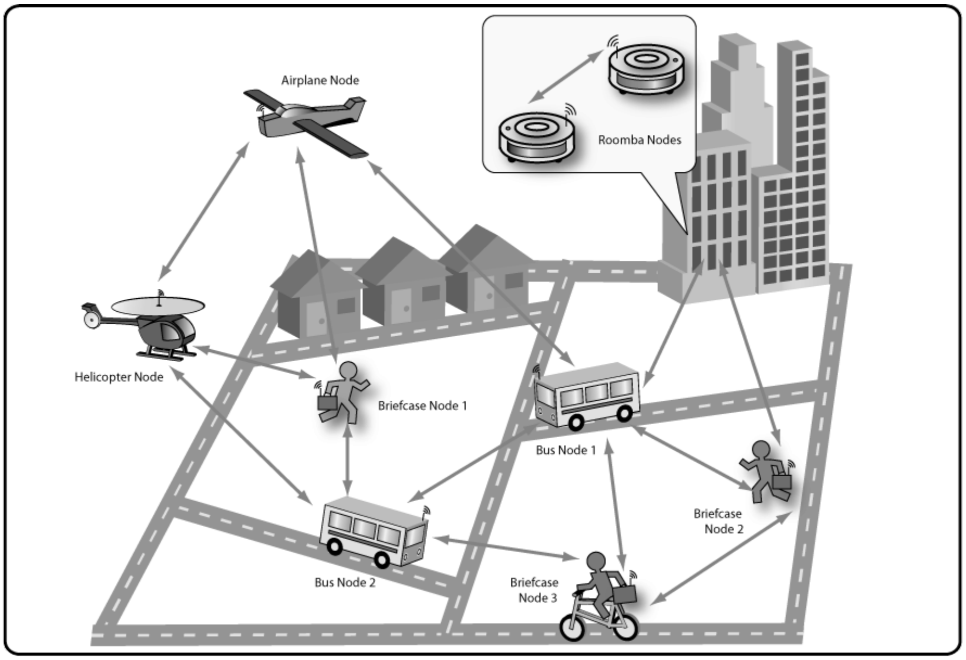

Figure 1: Its diverse set of nodes makes SCORPION suitable for experiments and evaluations under the most vast set of mobility applications.

Harvard's MoteLab [12] is a sensor network testbed that utilizes Berkeley Motes [13] equipped with light, temperature, and humidity sensors. Developers are able to upload software, test protocols, and receive results using their desktop. MoteLab specifically targets static, connected, indoor sensor network scenarios.

While testbeds like MoteLab [8] embody static topology paradigms, others utilize mobile nodes to create a more dynamic network environment. The University of Utah's Emulab is oneexample. Emulab's remote-controlled robots create dynamic topologies which are ideal for testing wireless sensor network applications. Each mobile robot has sensory capabilities and can communicate through inanimate motes. While this approach to wireless networking takes testing to the next level, it still lacks heterogeneity.

SCORPION focuses on emulating a diverse network scenario consisting of nodes with different capabilities and mobility patterns. Airplanes nodes, helicopter nodes, human nodes, and bus nodes each carry SCORPION hardware, making it an effective tool for protocol deployment in a dynamic, heterogeneous network environment that approximates real-world deployments more closely.

In [3] authors describe a miniaturized 802.11b-based, mulli-hop wireless network testbed called MINT. This testbed occupies a significantly small space, and reduces the effort required for setting up a multi-hop wireless network used for wireless application/protocol testing and evaluation. An interesting feature described in [3] is the hybrid simulation functionality. Under this platform ns-2 simulations can be executed where the link, MAC and physical layer in the simulator are replaced by real hardware. They also compare experimental results on their testbed with similar experiments conducted on pure simulation plataforms.

II. Nodes

In its current version, SCORPION consists of 88 nodes: 40 bus nodes, 20 briefcase nodes, 20 iRobot nodes, and 8 aerial vehicle nodes.

II.A. Bus Nodes

Bus nodes are equipped with a mini-ITX [10] computer running Linux. Each bus node has three 802.11a/b/g radios [2], a GPS tracking device [9], and a 900MHz radio [1]. The 900MHz network formed by bus nodes is used to collect tracking information about the buses. This information will be used by UCSC's Transportation Department to better manage the campus bus network. Buses transmit their GPS location to base stations deployed throughout campus, which in turn relay location information to a server. The server publishes bus location information on the Internet which can be viewed in real-time through a Google-Maps based graphical user interface. The tracking information is logged and can be used in the form of mobility traces.

There are approximately thirty to forty buses running on the UCSC campus at any given time. The bus nodes use the 802.11 a/b/g radios to create an ideal platform for testing delay-tolerant networking (DTN) protocols. Additionally, the bus nodes collect rich GPS data sets for further analysis of different types of protocols (e.g., find where and when a connection was established).

II.B. Briefcase Nodes

All 20 briefcase nodes are equipped with three 802.11a/b/g radios [2]. They are also equipped with GPS receivers [9] for accurate location updates. The mainboard is a mini-ITX computer [10] running Linux Debian Etch. Each briefcase node is equipped with a laptop battery [5]. The electronics are encased using foam inside a waterproof Pelican case.

The idea is to distribute the nodes to people (e.g., students on the UCSC campus) who go about their daily routine, roaming the testbed area while constantly communicating with other nodes in the vicinity, regardless of the type. Using their GPS data, node location can be tracked (e.g., to determine whether specific nodes follow a particular mobility pattern).

II.C. Autonomous Ground Nodes

Similar to the briefcase nodes, the autonomous ground nodes use a mini-ITX computer running Linux Debian with three 802.11a/b/g radios. This hardware is carried by iRobot Create robots that can roam both in- and outdoors using various mobility patterns. One pattern is random waypoint, where the robots move in a chosen direction until they reach an obstacle then change direction. More specific mobility patterns can be created where the nodes follow predefined paths. The nodes can move in and out of contact with each other closely emulating mobility scenarios in real life ad-hoc networks in order to thoroughly test protocols.

II.D. Aerial Vehicles

Aerial vehicles add several nice features to the testbed. They are able to navigate over any terrain providing network connectivity to otherwise disconnected nodes, and they can cover wider areas in shorter periods of time since they can achieve higher speeds and avoid ground-based obstacles.

Four remote controlled, self-stabalizing helicopters and four autonomous airplanes have been integrated into SCORPION. The planes are equipped with autopilot hardware and software from the open source Paparazzi project [11]. The software allows the plane to circle GPS waypoints, fly between two waypoints, or survey an area defined by four waypoints. The aerial nodes are equipped with 802.11 radios that allow them to communicate with any other node in the network as well as bridge disconnected sections of the testbed.

III. Management

For management purposes, the network is divided into *nodes* and *gateways*. All nodes run a *management agent* that runs as a background process listening and executing commands transmitted by a gateway. Commands are encoded in the form of character strings at the gateway end. When a command is issued by the gateway, it is sent to a list of IP addresses corresponding to the testbed nodes over a UDP socket connection. After the management agent receives one of these commands at the node, it systematically checks the string against a list of registered commands and executes the statements associated with the matching case. Currently the agent will respond to status and power cycle requests.

Status requests are periodically issued by the gateway to ascertain which nodes it can communicate with. When the node receives a status request, it collects information pertaining to its system state that will help with diagnostics at the gateway. Information that the agent gathers includes IP address and host information, uptime, system temperature, kernel version, and versions of software running on the node. This information is funneled into an output file and transmitted over the same UDP socket connection.

Both the bus and briefcase nodes are given software updates using shell scripts accessing an SVN repository. When the nodes start, a bootup script is launched which invokes a series of scripts. Each child script will start a different background process, including management programs as well as networking protocols. Additionally, there is a scheduler script which has the ability to run software at specified time intervals. This lets the testbed to run several protocols during the length of a single deployment, allowing several researchers access simultaneously.

IV. Conclusion

In this paper we presented an overview of *SCORPION* (Santa Cruz mObile Radio Platform for Indoor and

Outdoor Networks), a heterogeneous wireless networking testbed that includes a variety of mobile nodes ranging from ground vehicles to autonomous aerial vehicles. An integral component of SCORPION is its management suite which automates node configuration, monitoring, trouble-shooting and testbed scheduling. The testbed is unique due to its node heterogeneity and consequently wide range of mobility scenarios that try to closely model real-world situations (e.g., applications that are prone to frequent, long-lived connectivity disruptions). SCORPION's distinct set of varying node mobility types allows for thorough testing of innovative protocols in the field of wireless networking.

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