Autoconfiguration and Self-management of Personal Area Networks: a New Framework

Second Year Report

Rui Lopes Campos

Advisor: Manuel Pereira Ricardo

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Abstract

During the second year of this PhD a major goal was expected to be achieved: the improvement of the solution proposed during the first year. For that purpose, the author enhanced the solution based on further design and specification and increased knowledge of the research topic being considered: autoconfiguration and self-management of Personal Area Networks.

This document reports the activities developed along the second year of this PhD, mentions the deviations from the work plan, and justifies them. In addition, it provides an overview of the current proposed solution, the relevant contributions expected for this PhD, and the work plan for the next year, which will mostly concentrate on the evaluation of the proposed solution.

Contents

Acronyms

ACM Advanced Connectivity Manager

ACP Advanced Connectivity Protocol

ASPAN Autoconfiguration and Self-management of Personal Area Networks

BCM Basic Connectivity Manager

BCP Basic Connectivity Protocol

DHCP Dynamic Host Configuration Protocol

FEUP Faculdade de Engenharia da Universidade do Porto

GTLP GANS Transport Layer Protocol

IEEE Institute of Electrical and Electronics Engineers

IETF Internet Engineering Task Force

INESC Porto Instituto de Engenharia e Sistemas de Computadores do Porto

IP Internet Protocol

NAT Network Address Translation

NGNs Next Generation Networks

NS-2 Network Simulator 2

PAN Personal Area Network

PhD Doctor of Philosophy

PoA Point of Attachment

UDP User Datagram Protocol

VoIP Voice over IP

WPAN Wireless PAN

1 Introduction

This section provides an overview of the problem scope in which the proposed solution fits in and defines the structure of the report.

1.1 Problem Scope Overview

Next Generation Networks (NGNs) will be characterized by a movement towards ubiquitous connectivity. This includes an increasing number of wireless and wired technologies, multi-homed devices, and mobility of networks and end-users. In this communication scenario, user intervention must be minimized and technology must seamlessly adapt to different networking contexts and user needs. The increasing number of devices expected to be carried by a person, combined with the integration of electronic devices having computing and communications capabilities within clothes, human environments, or even in the human body, will trigger the emergence of new computing environments and bring up new communication models; some of these devices will form cooperative networks, such as PANs. On the other hand, it becomes consensual that IP will be the base protocol for NGNs; Internet will play a central role, supporting multimedia data and services, such as web browsing, e-mail, VoIP and video-conferencing, and will be the network to which most of the devices need to be connected.

Small incipient cooperative networks, such as Bluetooth PANs, can already be created. However, they require manual configurations and networking expertise. Also, Bluetooth does not provide mechanisms to adapt automatically to scenarios where, for instance, a PAN is changing its point of attachment (PoA) to the Internet dynamically; other solutions, e.g., IEEE 802.15.4, are proposed for creating PANs but they care only about creating PANs at the data link layer. The deployment of Mobile Ad-hoc Networks, also known as MANETs, in a self-organized and spontaneous way has been a hot research topic during the last decade. The proposed solutions have been mostly based on routing protocols that work over IP and consider basic metrics (typically number of hops) to select the best path between any two devices in the network. Recently, new solutions have been proposed that consider more advanced metrics (e.g., power consumption, link stability) and even more than a single metric to perform such selection. However, all these solutions consider a static set of metrics that is selected during protocol design and typically holds forever.

In another plan, IP networks are also becoming heterogeneous; different protocol suites operate simultaneously (IPv4, IPv6), and multiple addressing schemes (private IPv4, public IPv4, IPv6) and autoconfiguration mechanisms coexist. Also, with the advent of new communication paradigms where entire networks connect to the Internet while moving around, new autoconfiguration mechanisms, apart from those already defined in IP networks (e.g., DHCP), may be required. In this context, enabling the automatic and dynamic creation of PANs, and dealing with its dynamic and automatic connection to the global Internet poses new requirements to mobile communication systems, particularly in terms of autoconfiguration and self-management.

1.2 Structure of the Report

This report is organized in four sections. Section 2 provides an overview of the proposed solution and presents the relevant contributions expected for this PhD. Section 3 provides the work plan for the second year, the actual activities developed, and mentions and justifies the mismatches. Section 4 specifies the work plan for the next year and, finally, Section 5 draws the conclusions.

2 Overview of the Proposed Solution

In this PhD we provide a new framework, the Autoconfiguration and Self-management of Personal Area Networks (ASPAN), which addresses the problems pointed out in Section 1.1. The design and specification of the ASPAN solution takes as a fundamental principle the easy migration from legacy networks. Therefore, two basic requirements drive its design and specification: 1) whenever possible use legacy mechanisms; 2) introduce no modifications to the data plane. By following this approach we expect to deploy our solution easily using legacy devices.

The ASPAN framework follows a master-slave model where a central device controls all mechanisms regarding the PAN internal organization and its connection to the Internet. From the internal point of view, the framework defines two ways for interconnecting PAN devices: 1) bridging mechanism; 2) routing mechanism (not further specified in this PhD). The bridging mechanism is specified based on the following concepts: learning bridge, multi-objective spanning tree, and the innovative concept of user-defined dynamic set of metrics, which enables the user to control the way PAN devices are interconnected – for instance, if at some point in time the user aims at optimizing both connectivity to the Internet and power consumption she will select the corresponding policy for that; this triggers the selection of the proper set of metrics for computing the multi-objective spanning tree that interconnects the PAN devices. In order to deal with the heterogeneities within IP networks, ASPAN defines a mechanism for negotiating the proper IP version and autoconfiguration mechanism to be used within a PAN when different types of PAN devices (i.e., IPv4-only, IPv6-only, dual stack) come together to form the network. From the external connectivity point of view, ASPAN deals with the connection of the PAN to the Internet through the best access network according to user-defined policies; it also copes with the required configurations to enable that, for instance, selection of the proper IP version and autoconfiguration mechanism to be used within the PAN regarding the selected access network. Further details about the ASPAN framework can be found in [2] [3].

2.1 Relevant Contributions

The following relevant contributions are expected to be provided by this PhD:

1. **Mechanism for PAN and device configuration according to user-defined policies that supports legacy IP autoconfiguration mechanisms in multi-hop scenarios in a fully transparent way**. We provide a layer 2 solution for interconnecting PAN devices supporting different wired/wireless technologies, such as WLAN, Bluetooth, Ethernet. The links used to interconnect the PAN devices are

selected based on a dynamic set of metrics that is indirectly controlled by the user through user-defined policies. The major advantages of this mechanism are: 1) transparent support of legacy IP autoconfiguration mechanisms (e.g., DHCP) in multi-hop scenarios; 2) adaptation of the PAN topology according to the user context/preferences.

2. **Centralized mechanism for selecting the best PointOfAttachment towards the Internet based on user policies/network context**. Currently, the automatic and dynamic selection of the best PointOfAttachment towards the Internet is possible in stand-alone terminals, such as laptops, by means of internal policies of the operating system. Our mechanism extends this to the context of networks (e.g., PANs) and considers its selection based on user-defined policies. It includes the execution of the procedures needed to reconfigure a PAN when it changes its PoA, for instance, the reconfiguration of resources (configuration as IPv4 router or as a bridge) and services (NAT, DHCP) in each device. In the literature we can find mechanisms addressing the same problem by following a distributed approach. Our mechanism follows a centralized approach that is more suitable for PANs from our standpoint.

3. **Mechanism for negotiating the proper IP version and autoconfiguration to be used within a PAN**. This mechanism deals with the heterogeneities coming up from the two IP versions and multiple autoconfiguration frameworks coexisting in IP networks, and establishes basic IP connectivity when two or more devices or networks get contact with each other. It is expected to improve the efficiency of the autoconfiguration process in heterogeneous dynamic communication scenario where multiple (dis)connections between networks are envisioned to occur.

3 Work Plan for Second Year

This section describes the activities planned at the end of the first year, presents the actual activities performed, and specifies the parts of the plan that were not fulfilled and the reasons for that.

3.1 Planned Activities

The plan for the second year at the end of the first year [1] is presented below; Figure 1 shows the corresponding Gantt Chart.

The following set of activities was planned:

1. Rough specification of the protocols used between Basic Connectivity Managers (BCMs) and Advanced Connectivity Managers (ACMs), Basic Connectivity Protocol (BCP) and Advanced Connectivity Protocol (ACP), respectively
2. Specification of the election algorithm used by the BCMs to elect a master between them
3. Implementation of the BCM and ACM over NS-2;
4. Simulations on the basic connectivity mechanism implemented by the BCM using the BCP protocol
    - Comparison with overhead introduced by the current autoconfiguration process, where autoconfiguration mechanisms associated to IPv4 and IPv6 run independently and at the same time, regardless the IP version actually supported;
    - Evaluation of the signalling overhead introduced by our solution
5. Simulations on the advanced connectivity mechanism providing self-management for small moving networks;
    - Simulations without using the GTLP under the ACP protocol
    - Simulations using GTLP under ACP
6. Second year report write-up

The focus of the preliminary solution proposed in [1] was IP autoconfiguration for Next Generation Networks (NGNs); in [1] we have provided the typical scenario being addressed and the architecture model of the solution that considers two managers (BCM and ACM). At a first phase, we planned to design and specify the solution addressing IP autoconfiguration for NGNs, including an election algorithm to select the central device that handles the IP autoconfiguration process. Subsequently, we expected

ID	Task Name	Start	Finish	Duration
1	Rough Design of BCM and ACM, and rough specification of the BCP and ACP protocols	19-09-2005	15-12-2005	64d
2	Election algorithm for BCMs	16-12-2005	10-01-2006	18d
3	Implementation of the BCM and ACM over NS-2	11-01-2006	07-04-2006	63d
4	Simulation of the BCM and BCP	10-04-2006	10-05-2006	23d
5	Simulation of the ACM and BCP without using GTLP	11-05-2006	09-06-2006	22d
6	Simulation of the ACM and BCP using GTLP	12-06-2006	14-07-2006	25d
7	Second year Report write-up	17-07-2006	31-07-2006	11d

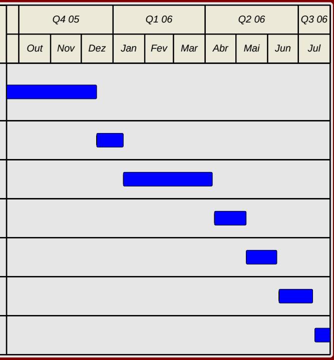

Figure 1: Planned Schedule for the second year.

to simulate the solution considering: 1) the comparison between the IP autoconfiguration process using our solution and using only legacy mechanisms, from efficiency viewpoint; 2) the advanced connectivity mechanism dealing with the connection to the Internet; 3) the performance analysis of the Advanced Connectivity Protocol (ACP) when running directly over UDP and when running over GTLP (GTLP is a protocol being specified in the IST Ambient Networks project for transporting signaling information between Ambient Networks). Essentially, the schedule concentrated on the design, specification, and simulation of a solution addressing IP autoconfiguration issues for NGNs, namely dealing with the heterogeneities in IP networks (i.e., different protocol versions and multiple autoconfiguration mechanisms). Even though it already implicitly considered the specific case of PANs, the preliminary solution did not concentrated on the specific mechanisms required to bootstrap and fully self-manage a moving PAN, namely in multi-hop scenarios, as we actually did (see Section 3.2).

3.2 Actual Activities Performed

We now describe the actual activities developed along the second year. We anticipate that the planned activities were performed until almost the middle of the second year; after that, the plan was abandoned. The reasons for that are mentioned in Section 3.3.

The following set of activities was carried out:

1. Design and specification of the solution considering:

    - Definition of assumptions, goals, and requirements for the AS-PAN framework
    - Definition of two different perspectives for the final solution: 1)intra-PAN connectivity; 2) external PAN connectivity.

- Draft of the ASPAN framework released and published through two peer-reviewed conference papers [2] [3]

2. Specification of the master election and topology discovery algorithm

    - state of the art review and selection of an existing master election algorithm that suited our goals
    - definition of a topology discovery mechanism embedeed in the adopted master election algorithm

3. Specification of a layer 2 solution based on the concepts of learning brigde and multi-objective spanning trees

    - state of the art review on single and multi-objective spanning tree algorithms
    - definition of a mechanism for creating a multi-objective spanning tree that takes into account a set of up to three different parameters (power consumption, data rate, and external access potential)

4. Implementation of the solution over NS-2 for evaluation purposes (ongoing work)

ID	Task Name	Start	Finish	Duration
1	Design and specification of the solution	19-09-2005	31-01-2006	97d
2	Specification of master election and topology discovery algorithm	01-02-2006	15-03-2006	31d
3	Specification of layer 2 solution for creating PANs	03-04-2006	09-06-2006	50d
4	Implementation over NS-2	12-06-2006	14-07-2006	25d
5	Second year Report write-up	17-07-2006	31-07-2006	11d

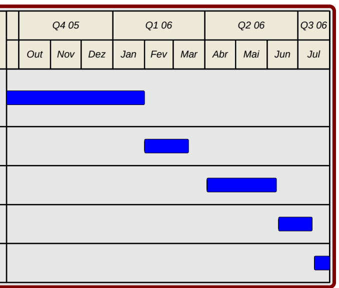

Figure 2: Actual Schedule for the second year.

At a first phase, we concentrated on the design and specification of the ASPAN framework, including an election algorithm that has embedded a topology discovery mechanism, i.e., a way to find out what devices are available to form the PAN and the links available to interconnect them. In a subsequent phase, we specified a layer 2 mechanism for selection the actual links used to interconnect the PAN devices based on three concepts: learning bridge, multi-objective spanning tree, and user-defined dynamic set of metrics (see Section 2). This mechanism makes the current solution go beyond the autoconfiguration and self-management of PANs from IP point of view considered in the preliminary solution; it addresses the bootstrapping and self-management of multi-hop PANs by using a layer 2 mechanism that enables the transparent operation of legacy IP autoconfiguration mechanisms in multi-hop scenarios. In a final phase, we started the implementation of the proposed solution over NS-2 concerning its evaluation.

3.3 Mismatches

By comparing the work plan presented in Section 3.1 with the actual activities developed along the second year, we find some mismatches. Basically, until the activity concerning the specification of an algorithm for master election everything went as planned, in spite of some delay caused by the extensions introduced in the solution. After that, we followed a different direction. Firstly, because we decided to focus a bit more on the PAN internal issues, such as the bootstrapping process and all issues related to the management of the PAN while it is up and running (e.g., joining and leaving of devices in multi-hop scenarios); secondly, because we decided to concentrate on the specification of the layer 2 mechanism referred in the previous section. Thereby, as we decided to go deeper in the specification of the solution, and the work plan specified the simulation of the mechanisms defined in the preliminary solution, a different schedule was followed afterwards. On the other hand, the progressive changes introduced in the solution rendered the planned simulations inadequate for its evaluation. Also, some of the protocols considered in the preliminary solution (e.g., GTLP and ACP) are not considered anymore in the current solution. As such, we have postponed the simulations for the next year.

4 Work Plan for Third Year

This section presents the work plan for the next year. We provide a Gantt Chart with the work plan (Figure 3) and a brief description of each activity to be carried out. The work plan is divided in three phases; before entering the first phase we aim at finishing the first implementation of the solution over NS-2.

In a first phase, we intend to perform the first round of simulations considering simple wireless communication scenarios and the mechanisms considered in the ASPAN solution, such as: the master election and topology discovery mechanism, the mechanism for creating multi-objective spanning trees, and the mechanism dealing with join/leave of PAN devices. The solution will be evaluated concerning the following parameters: signalling overhead, user data throughput, power consumption, and time to adapt to changes in PAN topology; a comparison with other solution, such as ad-hoc routing protocols (AODV, OLSR) and WPAN technologies (IEEE 802.15), will be performed as well. At the end of this phase, dissemination of results is planned through a conference paper.

In a second phase, we will improve the solution regarding initial simulation results. Additionally, by considering more complex scenarios, we will perform the second round of simulations in order to further evaluate the mechanisms mentioned above; a comparison with other solutions will be accomplished again. The dissemination of the new findings and results is expected through a magazine/journal paper.

At the third phase, we will perform further specification of the mechanisms allowing the connection of a PAN to the Internet and the third round of simulations considering the PAN as a moving network connecting to the Internet; a comparison with other solutions is expected. The dissemination of results through a magazine/journal paper is planned at the end of this phase. The third year will end with the writing of the third year report.

ID	Task Name	Start	Finish	Duration
1	Implementation of the solution over NS-2 (continuation)	11-09-2006	29-09-2006	15d
2	First round of simulations; dissemination of results (paper)	02-10-2006	29-12-2006	65d
3	Second round of simulations; dissemination of results (paper)	02-01-2007	13-04-2007	74d
4	Third round of simulations; dissemination of results (paper)	16-04-2007	17-07-2007	67d
5	Third year report write-up	18-07-2007	31-07-2007	10d

Figure 3: Planned Schedule for the Third Year.

5 Conclusion

This document reported the activities performed along the second year of this PhD, the deviations from the plan, and the reasons for that. In addition, it provided an overview of the problem scope, described briefly the ASPAN solution we propose to address the problem, and pointed out the relevant contributions expected for this PhD. Finally, the work plan for the next year was described.

We may say that the objectives for the second year of the PhD were fulfilled. We came up with a solution that enhances the solution proposed at the end of the first year and have identified three relevant contributions to the state of the art. In the next period, we will start evaluating the solution by means of simulations; firstly by concentrating on intra-PAN connectivity and secondly by focusing on the connection of a PAN to the Internet. The new findings and results are expected to be disseminated through publications.

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