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Session 6 - Environmental Systems: Management and Optimisation

Session 7 - New Methods and Technologies for Medicine and Biology

Session 8 - Embedded System Design and Application

Session 9 - Image Processing, Image Analysis and Computer Vision

Session 10 - Mobile Communications

Session 11 - Education in Computer Science and Automation

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Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.

Professor Peter Scharff
Rector, TU Ilmenau

Professor Christoph Ament
Head of Organisation

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52nd Internationales Wissenschaftliches Kolloquium
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Steffen Schmidt, Holger Kärst, Andreas Mitschele-Thiel

Towards Cost-Effective Area-wide Wi-Fi Provisioning

ABSTRACT

Wi-Fi provides small cells resulting in a huge amount of Access Points necessary to obtain an adequate coverage. This directly leads to enormous network cost.
This paper proposes a revolutionary platform, referred to as ZONOS, which allows for a cost effective installation and operation of a carrier grade Wi-Fi network, offering public wireless access points.
This is achieved by CUCULUS, using private Access Points, whereby a part (meaning resources like CPU cycles, RAM, Flash or Interfaces) of each Access Point is virtually given back to a large provider. Those Access Points can be shared between private users and an Internet Service Provider. A sharing process may be initiated on-demand and is as simple as ordering any product in an online-shop. The process includes a self-configuration of the device meaning a logical but secure separation of so called zones within the Access Point. Internal security is provided by an integrated certificate management system and an independent control unit. One of the zones of the so configured Access Point is then automatically registered with the provider. Every zone behaves like a physical device. The control unit supports negotiation processes between the parties of the shared device. No party of the Access Point has the ability to influence, may be due to configuration processes, the functionality of any other zone without the acceptance of the affected party. Thus, the platform ZONOS enables various parties to use the same physical device securely.
A provider can use its own monitoring and control tools to manage the new part of its network. A secure user communication by means of a ZONOS enabled Access Point is realized both by WPA encryption on the wireless and SSL tunnelling on the wired part of the path.
From the management point of view CUCULUS means that new approaches have to be invented and studied. Currently known and often centralized solutions cannot be applied to networks of the resulting size. Today very large networks consist of several 10s of thousands of devices. If private devices are included the size will grow up to several 100 thousand or even million devices. In this paper we will additionally present the challenges for network management that have to be faced in these networks foreseen in the future.
The uniform area-wide low-cost access using Wi-Fi networks will revolutionize the entire mobile and stationary communication. New services and use cases will open up new markets for the applying providers.

INTRODUCTION

While almost 300 million people worldwide use wired fast broadband connections for accessing the internet, wireless broadband access everywhere is still a dream. The reason is, that establishing and operating a public Wi-Fi infrastructure supporting area-wide coverage nowadays causes enormous network cost. Wi-Fi provides small radio cells so that it requires a huge amount of Access Points for obtaining a sufficient coverage. For those Access Points the operator of a Wi-Fi network has capital expenditure (capex) for the Access Points themselves, the installation and sites of the Access Points. Also, operating expenditure (opex) for power, connecting the Access Point to a wired broadband access, rental fee for the site of the Access Point and more lead to high costs. A brief overview of capex and opex is provided in Tables 1 and 2.

Item	Unit Cost	Total Cost
Hardware	$504	$3.528.000
Software		$3.000.000
Site Survey	$450	$2.250.000
Installation/Configuration	$544	$2.720.000
Total	**$1498**	**$11.498.000**

Table 1: Capex for providing a public Wi-Fi with 7000 Access Points ([2])

Item	Unit Cost	Total Cost
Broadband Access Backbone	$185	$11.100.000
Backoffice		$13.573.800
Support/Maintenance		$2.250.000
Total	**$185**	**$21.373.800**

Table 2: Opex per year for providing a public Wi-Fi with 7000 Access Points ([2])

Furthermore, every country has its own special laws and regularities for providing Wi-Fi networks. Restrictions to transmission power, the usage of radio frequencies or laws for securing Wi-Fi-networks are examples.

Therefore a huge amount of customers is necessary for providing a profitable Wi-Fi network. Customers, however, cannot be attained only by providing to them a simple transport service over a wireless broadband access. Customers want to use innovative services which can be offered having an already established wireless broadband access. However, due to the high capex and opex nowadays a Wi-Fi network can only be cost-efficient if no changes for the infrastructure are necessary for a long period of time. Following these restrictions, providers of networks are limited in innovation and flexibility, meaning the rollout of new services for customers is difficult, too expensive and therefore too slow for increasing the group of wireless users significantly.

To break this loop this paper presents a new approach, referred to as CUCULUS, which allows for a cost effective installation and operation of a carrier grade Wi-Fi network. It will support to achieve the target of area wide Wi-Fi provisioning and innovation in wireless networks. The concept of CUCULUS is based on using infrastructure multiple times by several parties in parallel, whereas for every party its zone appears to be stand-alone. As an example, the paper describes the CUCULUS principle by sharing private Access Points between their owners and providers of public Wi-Fi networks. The potential of parallel usage of Access Points providing a private as well as a public Wi-Fi will be supported by the novel platform ZONOS. ZONOS allows for sharing of infrastructure by partitioning the physical devices into logical encapsulated zones controlled by a secure and independent control unit.

THE CUCULUS TECHNOLOGY AND ZONOS®

The most common and largely preferred broadband internet access technology today is DSL. As stated in [1], the number of DSL connections has risen over 200 million and still increases by approximately 30% per year. In Germany alone more than 15 million DSL users are registered, most of whom are customers of one of the major DSL providers.
Commonly nowadays, a DSL connection comes with a wireless DSL router, to supply the household with a wireless connection (Wi-Fi / WLAN) to the internet. This leads to a high Wi-Fi coverage, whereas the wireless medium may only be used by the owner of the DSL router. Using the already available private Wi-Fi infrastructure connected by broadband access to the internet (mostly DSL) to provide public Wi-Fi hotspots in parallel, the dream of wireless access everywhere will take one step further to reality.
Built up and maintenance for public networks, supported by private equipment will be significantly more cost efficient than today's wireless networks are. The high operational expenditure will be distributed between all parties participating in the network. Different organizations have taken up this idea forming so-called Wi-Fi communities. Those approaches rely on the agreement of private DSL users to give other people free access to their Wi-Fi network, thereby use their DSL account and providing a community hotspot. This issue, however, directly leads to significant deficiencies concerning legal issues, privacy and security. When opening their DSL / Wi-Fi to other, commonly unknown users, the owner of the DSL account has to take responsibility of all the actions taken using this account. Furthermore, the private network of the DSL user is exposed to foreigners, that might very likely access, retrieve or manipulate private data. Even if the people accessing the hotspot are registered within the community, there is no guarantee provided, that the registration information is valid. For those and several other reasons community hotspots are limited to a specific user group and not suitable for the mass market resulting in very low coverage and acceptance.
To exclude all the disadvantages of community hotspots and thereby providing a reliable, area-wide public Wi-Fi network, CUCULUS has been developed. This technology allows for the secure usage of hardware devices and existing infrastructure by several independent parties without influencing one another. This creates the possibility of using private Wi-Fi router devices in parallel by their private owner and an Internet Service Provider. Both parties posses a certain amount of the device (a so-called zone) and are able to manage and configure their dedicated zone on the hardware device independently. One physical device behaves as several completely separated devices. This enables the Internet Service Provider to establish a public Wi-Fi hotspot encapsulated in one zone within the private wireless router. This mechanism releases the private DSL user of all the responsibilities connected to the public Wi-Fi access, which are now transferred to the Internet Service Provider. Additionally it strongly secures the private network against intrusion, building up a highly reliable security frame, isolating both zones and thereby separating the resulting networks from each other. Table 3 summarizes the most important advantages of the CUCULUS approach over Wi-Fi communities.

CUCULUS Technology (ZONOS)	Community Approach
Every party controls its own part of the device independently.	Everything is under the control of the community.
Real device sharing	Only different SSIDs
Security by design	Open by concept
A user has to be identified and authorized	No user identification
Risks are bound to parts	Risks are shared by concept
Hardware independent	Dedicated hardware
Efficient management by providers	Managed by the community.

Table 3: Comparison CUCULUS vs. Community Approach

The core technology building the foundation of CUCULUS is formed by ZONOS, the ZONed Operation System. A schematic overview of ZONOS is given in Figure 1. ZONOS is a Linux-based operating system allowing for the secure, logical separation of hardware devices into several independent zones. All zones may be configured and managed separately, without influencing one another. No user of a zone can gain root access to the whole device, only for the zone itself. For management and control functions, ZONOS provides a Control Unit that autonomously handles the coordination between the different zones, distributes device resources and ensures the secure separation and independence of the zones. The hardware device may be separated / shared in terms of bandwidth, CPU cycles, RAM, File System and interfaces.

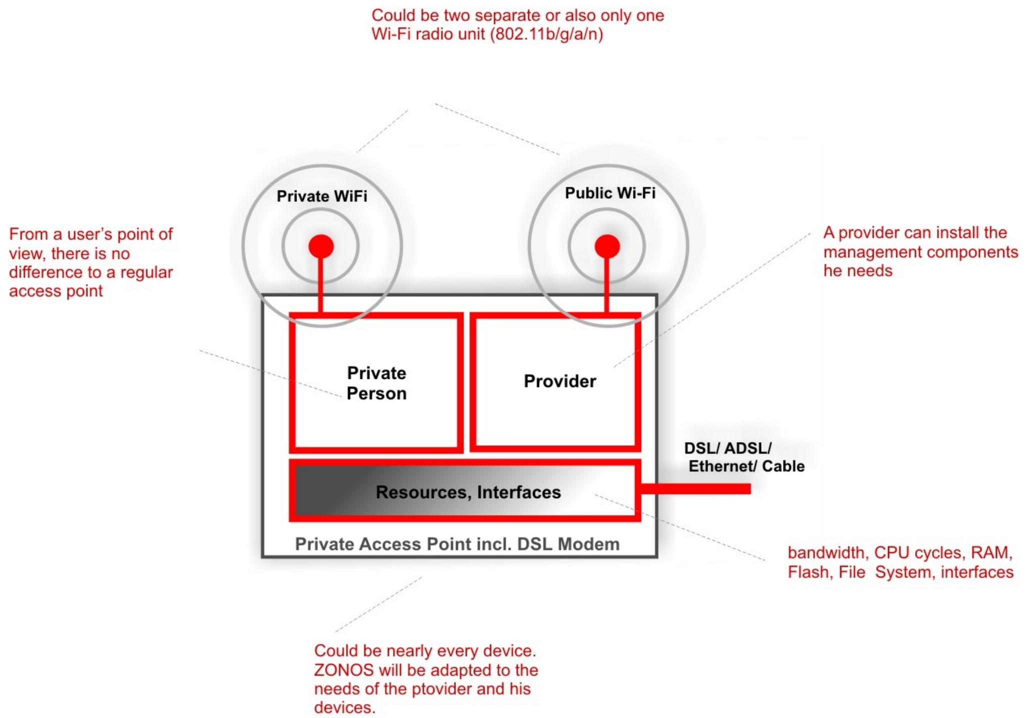

Figure 1: ZONOS - Overview

ZONOS requires very limited hardware resources and is widely portable to a large variety of hardware platforms for embedded and non-embedded devices.
Additionally, ZONOS strictly follows a service oriented approach. Because of the independent manageability and configurability of all zones contained within a ZONOS device, ZONOS supports and features the installation of different services

within a zone, as to adapt the device to certain requirements. This feature creates the capability for service providers to migrate services directly to the public access point, enabling for mobile or location-based services, as well as the presentation of context-sensitive information to mobile users of the hot spot.
In every zone a different service set can be installed and configured independently. New services and service architectures can be developed and distributed, leading to unknown possibilities. The CUCULUS Technology, based on ZONOS, thereby leads to the creation of provider-driven, carrier-grade, encapsulated hotspots.

MANAGEMENT CHALLENGES

From the CUCULUS approach two major challenges arise. The first challenge concerns the sheer size of the resulting network structure managed by a single provider. Current wireless access network structures include up to a number several thousands of access points. Applying CUCULUS this number increases within a very short time to several 100s of thousands or even millions of devices to be managed. The numbers directly correlate with the earlier described number of DSL accounts belonging to a provider.
This fact demands the re-design of management structures, interfaces, mechanisms and facilities to achieve a reliable and secure approach to managing and configuring the Wi-Fi devices. This effort contains AAA (Authentication, Authorization and Accounting) mechanisms, fault and availability management to present reliable network and service structures, as well as configuration management, guaranteeing a minimal influence of Wi-Fi devices on each other and a broad coverage of services within the Wi-Fi network. To decrease the management effort the separation of three types of providers was proposed in [3]. The Infrastructure providers offer their physical network resources to management providers. Management providers integrate the offered infrastructure in their management domain whereas their customers, the service providers use the managed network for providing services like VoIP or IPTV.
The second challenge in management will arise due to the possibility of ZONOS allowing the installation of services on Access Points directly. Thus, services can be moved from the core network to the network edges. The Access Points will become a kind of service platform, whereas the provided service set can be adapted every time easily and flexible. On one side it will enhance the reliability and QoS for services, because the service provisioning can be fast and flexible adapted to the current service utilization. New options for load balancing as well as moving of services between locations will be possible due to the huge amount of available interconnected service platforms. On the other side new challenges for managing the distributed services arise. The complexity for management will increase enormously.
Optimization problems have to be solved determining an optimal placement for services so that the service level agreements are fulfilled whereas the service provisioning is as cost effective as possible. An optimal set-up of infrastructure has to be found by selecting shared resources corresponding to the demand for service provisioning. This set-up varies between locations. The complexity will arise again if services haven't got a fix location any more so that during the runtime of services a replacement can occur. The service resources as well as the state of the service could be moved whereas for the user of the service the replacement must be transparent.
Furthermore the configuration management becomes more complex. For any service platform at any time this service configuration has to be known so that in case of

failures the service set can be installed on a fallback platform with the same configuration. Reconfiguration of this interconnected service platforms is quite difficult because of dependencies between them. The dependencies arise on one side due to the service distribution within service chains in case of one service needing another service to run correctly. On the other side services could also disturb each other. For example, neighbouring Access Points configured to communicate over the same radio frequency will generate interferences.
Summarized, the new point of interest for research is that an infrastructure based on CUCULUS is highly dynamic in availability and interconnection of network elements, as well as in service provisioning. At any time new network elements could appear whereas other ones leaf the network. Services change location dynamically adapting the network to the current demand.
Since 2001 several activities in research are observable engaging with complexity degradation proposing self- or autonomous network management [4, 5]. These activities should be strengthened, so that future networks with expected enhanced functionalities and size will be manageable.

CONCLUSION

The CUCULUS technology, based on ZONOS, offers the ability for the creation of an area-wide broad-band internet access and thereby a wide range of possibilities. It, by design, includes security mechanisms and creates capabilities for yet unknown new service structures and usage scenarios. CUCULUS seamlessly integrates into existing provider systems and is therefore a great step forward to the internet of the future. However, it requires new approaches for fault-, configuration-, performance and service management taking into account the new kind of infrastructure and service provisioning. It must be determined, whether centralized management approaches are still able to handle the new challenges or decentralized solutions would be able to solve this complexity in a better way.

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