AAU Ph.D. Degree

Updated plan of research

Title

Energy Aware Management for Internet of Things

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Application for enrollment/Registration as a PhD study

Ph.D. Programme:	Wireless Communications
Project title:	Energy aware Management for Internet of Things
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Date of enrolment:	15 Nov, 2009
Expected date of Completion:	14 Nov, 2012

Signature

Sulakshana.

Date 03/12/2012 Ph.D. student

Study Plan Approved

Date 24-8-2012	Academic Supervisor	Prof. Albena Mihovska
Date	Academic Co-supervisor	Prof. R. V. Raja Kumar
Date	Head of Department	Prof. Børge Lindberg
Date	Head of PhD program	Gert Frølund Pedersen

Contents

1. Project Summary/Abstract

An Internet of Things (IoT) scenario is characterized by heterogeneity found in the types of participating nodes, networks and type of data exchange. This creates a complicated scenario in relation to decision making, management and reliability.

The proposed research focuses on the design and evaluation of a management framework for an IoT scenario. Such framework will need to support algorithms and mechanisms for autonomous self-x mechanism mainly utilized for various tasks to control the operation of the IoT network. These autonomous solutions concern the management of nodes (devices that may or may not be foreseen with autonomic capabilities), autonomous decision making loops, autonomous radio access technology and operator selection, autonomous protocol reconfiguration and autonomously self-organizing network elements. Autonomic network improves ability of networks to cope with unpredicted changes like changes in topology, load, tasks, the physical and logical characteristics of networks that can be accessed. It enables users to focus on things other than configuring and managing networks by introducing some self-* characteristics.

The PhD research will propose, design and evaluate in terms of energy efficiency (e.g., reduced number of interactions during decision information exchange) algorithms and protocols for enabling dynamic, ad-hoc and optimized resource allocation and control in an IoT scenario. The main research focus is on inter-working the autonomic/self-* features across the different functional planes as well as within the data and control planes. Automation makes the network energy aware.

The future network can support the optimal choice of an autonomic optimization strategy related to the requirement for given scenario subsystem capabilities (e.g., energy efficiency, load balancing). This would mean introducing into it self-management capabilities, that guarantee service aware resource allocation and configuration of network resources.

2 Scientific contents of PhD project

2.1 Background

IoT is a complex system. It is quite important to comprehend how it actually operates. This requires basic research on network modelling and simulation, e.g., in order to derive the fundamental laws on network dynamics and control or to evaluate the ultimate capacity of self-organized wireless networks.

Recently, virtualization of resources has been proposed as a means to manage heterogeneous networks interconnecting in the world of the Future Internet. Virtualization describes the technique of emulating some nonexistent piece of hardware and/or software in order to abstract away from the real environment. Network virtualization provides an abstraction that hides the complexity of the underlying network resources and enables isolation-based protection, encouraging resource sharing by multiple network and application services.

The main characteristic of the IoT scenario is heterogeneity, large number of nodes, closely or remotely located and the need for making these cooperate in order to deliver services seamlessly across multiple domains. Resources in such an environment are needed for ensuring among others also reliability of the communicated information.

This PhD work will design, evaluate and implement a management architecture that allows the interworking and integration of the multi-domain networks and nodes comprising the IoT environment. In heterogeneous network it is necessary to enable sufficient resources available for various scenarios. The main objective is to make the integration feasible. It is proposed here that this is achieved by implementing self-organization and self-optimization capabilities into nodes and networks in order to manage the complexity. This, in turn, can be achieved by applying the cognition ability to underlying network environments, providing robust support for faster decision making and optimization process at the network level. Such an approach will enable that a node can monitor its environment in order to collect useful information before taking a decision. The decision must be autonomous, and based on previous knowledge, context information, etc. depending on the arisen scenario; the decision may require a protocol configuration, or the organization of several nodes into clusters. Information can be gathered based on the propagation characteristics related to each object. A decision then can be issued based on a distributed inference approach and data fusion for the optimal choice of a self-governance management or optimization strategy related to the resource requirement for a given scenario subsystem and the overall system control (e.g., fault-tolerance, load balancing). The data and context sources and actuators interactions would be primarily based on an ad-hoc/mesh type of communication.

The conceptual architecture has to identify and evaluate to fulfill the design goal. The evolutionary path for the deployment has to be identified. The deployment is possible through virtualization, which will enable logically independent networks built on a common physical structure. New network functionalities and protocols could be deployed, but specialized networks could be provided by building overlay or underlay techniques running new protocol on top of or below the network and transport protocol. Here IoT can be defined as a world-wide network of uniquely addressable and interconnected objects based on standard communication protocols. It is essential to classify the objects based on metric and type application.

Introducing automatic network management means to enhance the utility of the network. The scope is to present autonomous, distributed solutions to provide flexibility and scalability for communication network in heterogeneous wireless environment. The solution can be found by using dynamic spectrum sharing or distributed resource allocation and cognitive device management using autonomous self-X [1]. We focus more on the second solution i.e. autonomous self-x solution. Energy consumption occurs in three domains, namely: sensing, data (signal) processing and communication [2]. Communication is the major consumer of energy. To reduce the communication hops, use of highly localized and distributed algorithms for networking is required. Further, communication channels between nodes must be established with few messages. This can be done by allowing the node to decide when to invite another node to join a connection or when to drop connection.

2.2 State of Art

Traditional networks were vertically integrated to provide tightly controlled services. Within systems the need for rapidly deployable systems in areas of high traffic density has pushed the architecture towards flatter designs. Autonomic network attempts maximum degree of flexibility and support functional scalability. Functional scaling means the network is able to extend both horizontally (functionality) as well as vertically (different way of integrating functionality) [3]. In networking, autonomicity relates to the capability of nodes to self-organize into a network through local interactions with neighboring devices [4] IoT involves automatic identification of things and services, communication, service selection and composition, resolution and invocation of services. IoT works in non deterministic, autonomous and intelligent entities or virtual objects that will act in full interoperability. In order to enable virtualization of the network resources, the architecture should be able to create virtual network resources to get an abstraction from the real network resources (local management). Based on this functionality, a self-organizing management (global management) of virtual network resources is enabled. This can be achieved by introducing virtualization mechanisms e.g., management interfaces that can access/provide the virtual resources when needed [5].

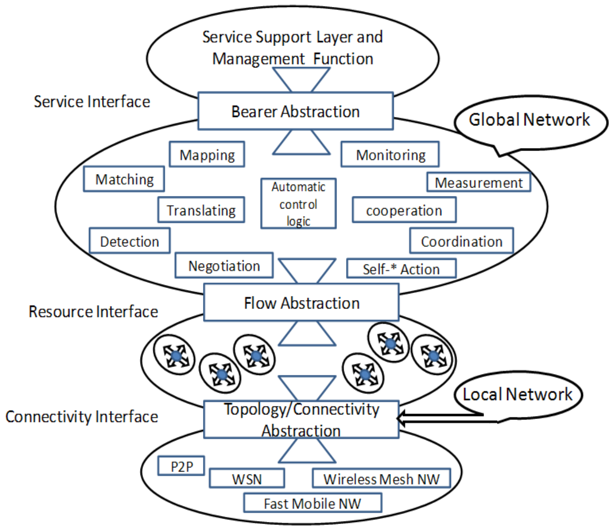

Figure 1:Conceptual Architecture

In the conceptual architecture the connectivity abstraction hides the differences of the heterogeneous internetworking technologies. Each network in the traffic network has traffic demand so gateway agents need to be deployed and interface model (connectivity interface, resource interface and service interface)in network such that total throughput is maximized.

An autonomic system offers an open environment for rapid and dynamic resource integration formed with no central authority leads to pervasive and ubiquitous computing. Proposed architecture consists of autonomic elements performing fixed function and interacting with other element in dynamic environment.

An IoT scenario implies global communication platform used by millions of devices working independently or cooperating with each other in large or small combinations or in shared or separated federations. The global platform implies not only communication resources, but also set of commonly agreed methods of communicating and operating. For reasons of flexibility, adaptability, mobility and survivability, the dominant means of access to and communication within the Internet of Things will be wireless. i.e. it allow the devices to communicate irrespective of their network topology and the data type.

A key aspect of this PhD work is the concept of self-organization. The ultimate vision of self organization is that network in which associated devices and services will be able to work in totally unsupervised manner. This PhD extends this concept further to the multi-domain autonomic [5] environment of the IoT. Further, other features of the self-* are also considered leading to the concept of the autonomous Internet.

A number of approaches have already been pursued. One very promising approach is that of the recently emerged evolvable holistic architectural Reference Model for Autonomicity/Self-management within node and network architectures, dubbed the Generic Autonomic Network Architecture (GANA) that has recently emerged from the EU-funded FP7 EFIPSANS project [6]. GANA introduces autonomic manager components known as Decision-Making-Elements (DMEs or in short - DEs) for different abstraction levels of functionality [7]. These autonomic manager components are designed following the principles of hierarchical, peering, and sibling relationships among each other within a node or network. Moreover, these components are capable of performing autonomic control of their associated Managed-Entities (MEs), as well as co-operating with each other in driving the self-managing features of the Network(s). Other similar already proposed architectures are 4D [8], Autonomic Network Architecture (ANA) [9], CONMan [10], a Knowledge Plane for the Internet [11], FOCALE [12], A situatedness-based Knowledge Plane for autonomic networking [13].

The main aspects of this PhD work are the autonomic functions in support of autonomic resource management [14]. Different types of Self-* functions will be introduced, ranging from advanced Auto-Discovery whereby devices discover services, capabilities (including roles) of network devices and networks, and are able to use the knowledge in dynamic context-aware Self-Configuration, to Self-healing, Self-Optimization and other types of Self-* features realized by Autonomic Control structures within node and network architectures. Currently, resource management in Beyond 3G Networks such as 3GPP LTE [15], ETSI NGN, Mobile WiMAX [16] etc. is performed on the basis of a policy infrastructure: a central Policy Decision Point enforces QoS and subscriber policies in Policy Enforcement Points located in the gateways to the respective network. Furthermore, user preferences or user policies are not considered. For example, it is not possible for the user to choose a particular QoS based on the device being used or to switch to a different device and a different QoS during the course of a session.

For future more flexible network environments, such as the IoT, this static, pre-configured model is no longer suitable. Network cooperation becomes more flexible, and the network landscape in general more heterogeneous. Further, the involved range of network types is more diverse: in an IoT scenario, there are sensor networks (wired and wireless), mesh networks, personal networks [17]. All these network elements and associated technologies etc. thus need to interwork, and furthermore this interworking needs to be arranged or adapted in an ad-hoc, automated fashion rather than by manual configuration.

A network of idle or lightly loaded workstations could achieve better performance. The load of network varies in unpredictable way as users come and go. Balancing the workload among all networks employed is central in achieving high performance. The workload can be either in the form of tasks or pieces of data. Schedule the incoming tasks to execute on lightly loaded network to improve average response time of whole network [18]. The autonomic resource management will be investigated in relation with efficiently handling load balancing and control.

The former network considers connectivity abstraction hide the network complexity (the differences of heterogeneous internetworking technologies) and enable applications to operate across them. A common naming framework enables end-to-end communication across otherwise independent internetworks and supports advanced networking capabilities such as delegation, through dynamic bindings between named entities. [19].

2.3 Project Objectives

- Definition of scenario and requirements.
- How to classify the objects/resources?
- Define resource allocation problem: what types of resources are needed to allocate?
- For autonomic resource allocation: decide who will manage what operation?
- Make Router Intelligent
- Implement self-organization and self optimization capabilities to make network integration feasible
- Different Communication protocols exist and how the proposed protocol will be extended for Internet of thing?

In the first year of research work I have completed the definition of scenario and requirements. IoT scenario consider the ad-hoc heterogeneity, large number of nodes, closely or remotely located and need for making these cooperate in order to deliver services seamlessly. The scope of IoT applications is to contribute to addressing societal challenges. The interconnection of physical objects is expected to intensify the effects that large scale networked communications has in society. To achieve this, we must consider the complex nature to IoT. The scenario, consider both peer to peer paradigm and client server paradigm. Future network can be autonomic network, where self management capabilities guarantee service aware resource allocation and configuration of network resources. We need to abstract the device parameters for its virtualization. The object classification can act as a guide to other device according to some pre-specified criteria eg. they can be judged as a good quality resources. Classified objects can be easily able to use in real time systems. The use of classification scheme gives context to search device used in network. Further we can partition and manipulate classified object classes. An object requires information only when writing to its attributes and this operation results in one or more direct information flows.

The resource may be a hardware device or software or link. We can define resource allocation problem as resources of different capacities must satisfy multiple demands. Resources have to be acquired, allocated motivated and manipulated. Here we are considering different resources for distributed applications like compute node, storage devices, visualization devices or network connectivity with dedicated QoS parameters.

Energy consumption occurs in domains like sensing, data processing and communication. Communication is major consumer of energy. Proposed protocol will help to design distributed algorithms for networking. Also it will assist to form communication channel between nodes with few messages, by allowing nodes to decide when to decide when to join or drop the connection.

Nodes can monitor its environments, providing support for faster decision. Decision must be autonomous and based on previous knowledge, context information, etc. Decision may require protocol configuration. A decision is then issued based on distributed interference approach.

It is a novel approach to categories to group the objects by using the subnet masking, because, the object which we classify are interdependent. The outcome of this work is to enhance the utility of network by using autonomic network management and virtualization of resources which manage heterogeneous network interconnection. In IoT scenario, any device/object may be a resource, it is necessary to classify the devices. After classifying the devices, it is essential to address them.

Here we propose how to achieve optimization of the resources by making the device intelligent rather than concentrating the intelligence in the node. The device may be a router. The intelligence is expressed in terms of context pattern. The device will decide which resource is allotted to which application and what should be the allocation time (Central management).

Later we will make few more intelligent devices which will share their intelligence and with the less interactions will accomplish the task which leads to energy efficient network (Distributed management).

In the second year of research work after literature survey, resource allocation or resource sharing I will use the concept of meshchord [20] algorithm as it shows recursive key lookup and is preferred when communication overheads need to be considered, to also observe the degree of load balancing. In the defined scenario of ad-hoc heterogeneous network, a distributed architecture peer-to-peer (P2P) technology is supporting. The protocols and topologies of the centralized P2P are the same as that of the client server design. At the same time, a completely distributed architecture is having complex topologies and protocols. The work proposes resource management through P2P architecture, to scale the size such that every end user on internet running a P2P without bothering network fragmentation and loss of search replies [21].

To make the router intelligent use, Vague Set Theory and WiRo (for non-IP based routing)[22]. The method will work on an updated information rather than the continuous resource management traffic.

As per the original time plan I have completed the first year objectives. Then I proposed and evaluated an object classification based on the device characteristic, which is again helpful while doing network virtualization. Work towards the second year objectives included an existing protocol comparison to decide on the need of distributed mechanism for on demand routing. Route establishment and optimization is performed as per the flow diagram shown in Figure 2.

A small deviation from the original time plan can be reported because of change in the software platform which demanded longer time more to understand the concept.

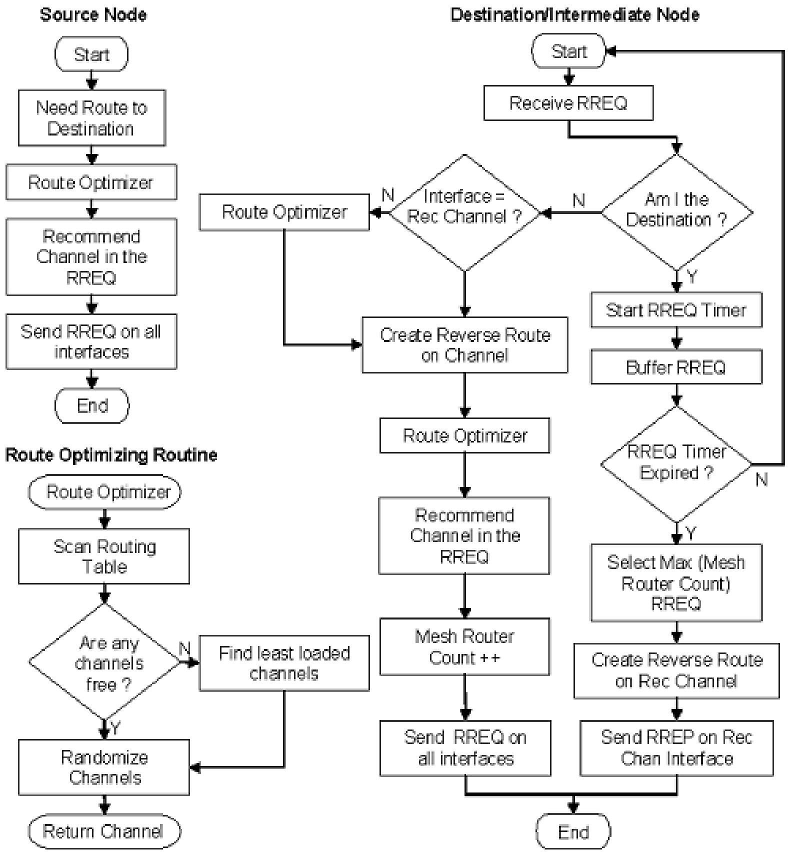

Figure 2:Route Establishment and Optimization

2.4 Key Methodology

In particular, the PhD work targets the following main objectives:

- Enabling of self—* functionalities for interworking of disparate multi-domain nodes and networks;
- Autonomous resource management framework for various IoT scenarios
- Protocols and algorithms for dynamic, ad hoc resource allocation and control.

The following specific objectives are defined in support of the main objectives:

1. Definition of usage scenarios and requirements (Year 1 objectives):
   a. Capture and specify the requirements, scenarios and use cases that reflect the need for the autonomic resource management of resources and self-* capabilities for the seamless provision of services in an IoT scenario.
   b. Using the Requirements, Scenarios and Use Cases, design the Overall Architecture and Design Principles for autonomous resource management in an IoT scenario.
2. Define decision models and algorithms for deriving and evaluating the overall optimality levels in autonomic resource management and operation: this work

will propose and design evolutionary algorithms for enabling the assessment and sharing of network resources, traffic prioritization and rerouting, self-healing and energy-aware resource optimization (year 1 and Year 2 objectives).

   a. Investigate the local and global performance of the system versus the types of nodes participating in a cluster/overall system view and their autonomicity level, traffic and QoS requirements. Fairness levels in resource usage/allocation as well as prioritization of data and traffic flows in cluster/system view and performance and scalability issues will be studied.

3. Integrate the above resource management components into a global framework (year 3 objectives):

   a. Define the physical and logical functionalities required for support of the decision protocols and resource management algorithms

   b. Evaluate the integrated framework in terms of delays, overhead and QoS requirements.

It is envisioned that both algorithms and architecture will be investigated through simulations in MATLAB or C++ environment.

2.5 Potential Significance and Application(s)

This PhD thesis has following contributions:

- Novel protocols for self configuration and real time information exchange.
- Integrated architecture that implements self management functionalities
- The algorithm for dynamic, ad hoc resource allocation and control.

The out come of this PhD work is to enhance the utility of network by using autonomic network management and virtualization of resources which manage heterogeneous network interconnection. To make integration feasible, it is proposed to use self organising capability. The autonomous decision is based on previous knowledge context information. It allows for reduced and reliable real time information exchange leading in turn to reduce signalling delays and faster decision making for a higher fairness level in resource usage/allocation as well as performance and scalability.

The proposed self-functionalities are supported by the architecture. This architecture interacts with the network equipment and protocols in order to configure the network with selected protocols and parameters. This improves network performance as it intends to confirm real time configuration of network equipment with ongoing situation in network.The autonomic resource management framework is enhanced by self-ware mechanism to exchange functionalities that control the behaviour of an element i.e. to control the communication between distributed things through network equipment. The reconfiguration affects the software, hardware and protocol stack. Reconfiguration is based on information shared by agents in the network. Agent has to select appropriate protocol. This work will bring better support energy consumption and new functionalities in IoT.

Applications

Application areas will include heterogeneous networks, enabling sensor network, IoT deployment and adaption, Telematics, Telehealth, Surveillance, autonomic network architecture, Military, Disaster etc. This is step forward from other architectures.

2.6 Time Plan with Milestones

Each box is equal to three months.

Task			**Year 1**				**Year 2**				**Year 3**			
1	Definition of scenario and requirements													
	1.1	Requirements, scenarios and use cases definition												
	1.2	Propose novel communication protocol for internet of things												
	1.3	Design of initial architecture												
2	Design Algorithms													
	2.1	Investigate performance of the system												
	2.2	Check fairness levels in resource usage												
3	Integration of resource management components and algorithms													
	3.1	Define physical and logical functionality required												
	3.2	Evaluate integrated framework in terms of delays												
4	Thesis writing													
5	Attending PhD Courses*													
6	Stay Abroad*													

2.7 Outline of content of the Thesis

Chapter1:	**Introduction** • Problem Definition • Key Research Issues • Technical Approach • Motivation for the Carried Out Research • Background • Research Scenario • Reference Architecture • Preview of this thesis
Chapter 2:	**Management Architecture** • Functional Requirements • Technical requirements

	• Physical /Logical Entities • Virtual Interfaces
Chapter 3:	**Decision Model and Algorithm for autonomous management for IoT** • Algorithm Design • Initial evaluation of proposed algorithm in relation to fairness, resource usage, scalability
Chapter4:	**Implementation** • Integration into architecture • Refinement and Optimization
Chapter 5:	**Performance Analysis**
Chapter 6:	**Conclusions and Future Work** • Conclusions • Future Work
Bibliography	

2.8 Tentative titles on papers

- Object classification Algorithm for IoT
- Framework of autonomic resource Management
- Integrated Management for Self management functionalities

3 Supervisor/ student co-operation agreements

Agreement on the relationship between supervisor and student (meeting frequency, communication forms, mutual expectations, etc.)

Weekly / through net in case of emergency.

4 Plan for PhD Course plan (both general and project-related courses) General courses should cover minimum 10 ECTS. Indicate topics to be covered if specific course names are not yet available. In general, no single course should exceed 6 ECTS credit points.

Courses adding up to 30 ECTS Credits*

Courses	Place/ Organizer	ECTS	Joint or Project course	Status
Introduction to Internet of Things	Nilee Prasad, Albena Mihovska, Zheng Hua Tan, Ole Brun Madsen,Aalborg	1	Project	Completed
Intellectual Property Rights	Lisbeth Tved Linde	2	Joint	Completed
Vehicle Communication	Tatiana Kozlova Madsen and Hans-Peter Schwefel	3	Project	Completed

Air Interface Design for Future Wireless Systems	Prof. Ramjee Prasad, Prof. Frederikson Suvra Shekhar Das, Nicola Marchetti	4	Joint	Completed
Sensors and RFID Networks	Neeli Rashmi Prasad, Prof. Pedro Jose Marron	3	Joint	Completed
Wireless Communications and Networks	Suvra Shekar Das, IIT Kharagpur, India	-	-	Completed
Distributed Source Coding and Multiple Description	Jan Østergaard	3	Joint	Completed
Performance Modeling of Communication Network	Tatiana V. Kozlova	1	Joint	Completed
Analysis And Design Of High Performance Future Internet Infrastructure	Jens Myrup Pedersen, M.Tahir Riaz, Anna Tzanakaki	2	Course	Completed
Bayesian Statistics, Simulation And Software - With A View To Application Examples	Kasper K. Berthelsen, Søren L. Buhl	4	Course	Completed
Theory and Practice of cognitive radio	Andrea Fabio Cattoni	3	Course	Completed
Low Power DSP System Design	Peter Koch	2	Course	Completed
Self Study*		6	Course	
Subtotal (Planned)				
Total (completed)		28		

5 Plan for fulfillment of knowledge dissemination

Most of the findings from the research work are going to be published in official conferences and included in the IEEE database according the standard proceedings. Furthermore, depending on the quality of the future results, other ways of dissemination -as newspaper articles, seminars, etc. will be considered. Depending on the solution and the application, some findings can be published as patents.

Publication Plan

Sr. No.	Conference Details: Name, scope, Date, Location, Web Site/ Journals
01	2013 International Conference on Information and Computer Networks(ICICN 2013) http://www.icicn.org/
02	Elsevier: Pervasive and Mobile Computing
03	IEEE Journal :Pervasive computing and communication
04	IEEE Conference on pervasive Computing

05	Wireless Personal Communications

6 Agreements on immaterial rights to patents

IPR may be claimed from the outcome of this PhD project.

Contribution to deliverables

Course may be delivered for master program on "Autonomic Networks".

Concept will be delivered in the International Workshop of GISFI in Lonavala, India on 26th – 28th Feb 2010.

7 External co-operation

According to time schedule, during the stay in India, will work in IIT laboratories, Kharagpur with consultation of Indian Supervisor.

8 Financing budget

The PhD is financed by Sinhgad Technical Education Society, Pune, India as per agreement between CTIF, Denmark and STES, Pune. AAU will provide all research facilities.

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