Function Centric Networking: an Approach for Addressing in In-Body Nano Networks

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ABSTRACT

We are looking at the combination of in-body nano communication with the Internet of Things (IoT) – especially Body Area Networks (BAN) – and the resulting research challenges in the Internet of Nano Things (IoNT). Moreover, our concept for Function Centric Networking presents an approach to deal with these challenges by addressing specific groups of interchangeable and replaceable nano machines.

1. INTRODUCTION

The downscaling of wireless micro devices allows us to think about in-body networks, consisting of nano machines to measure many more parameters from inside the body, e.g., blood and liver characteristics. So instead of going to medical facilities to take blood samples, we envision nanoscale machines in an in-body network to circulate through the patients blood and take measurements where- and whenever necessary and communicate their results to the outside. Nano machines equipped with actors may even be able to immediately respond to detected problems such as cancer cells.

Research on in-body communication or even nano communication itself is still in a very early stage. Instead of just downscaling technologies from micro to nano, additional possibilities inspired by nature arise, such as biological nano machines and molecular communication, e.g., cells communicating through diffusion-based calcium ion concentrations [1]. We are just starting to realize the potential of nano communication and adapting these new techniques for concepts in computer science. Particularly the interconnection of in-body nano communication devices with body area networks constitutes a number of new challenges [3].

In this paper, we take a look at what kind of addressing we really need for nano communication systems with an eye on in-body nano communication. Based on these considerations, we propose our own addressing concept which we call Function Centric Networking (FCN).

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2. CONSTRAINTS AND REQUIREMENTS

We are just starting to realize the potential of nano communication in its very early stage, but with every feature and opportunity that comes with nano communication networks, new challenges need to be addressed. Some challenges are already well known in the area of microscale devices but are driven into the extreme in the IoNT:

Energy management: Nano machines need a power source to stay online to measure, to act or to receive and send data. Batteries can take up a lot of space and may need replacement from time to time. Energy harvesting methods for renewable long term energy supply are unavoidable [5]. *Sparse memory and computation power:* Wireless sensor devices usually lack memory and processing power for complex implementations. In nano-size this issue increases even with new technologies like the highly efficient Carbon Nano Tube (CNT) transistors [4]. *Communication distance:* Radio communication in the range of megahertz radio waves using nano scaled antennas hasn't been possible yet. CNT antennas with their extremely good conductivity can operate in the terahertz range but suffer from atmospheric disturbances [2]. *Environment:* Sensor nodes can be damaged through harsh environmental conditions. The physical condition of a nano machine is almost impossible to fully control and preserve outside of a laboratory.

Nano machines are devices in size of a few hundred nanometers, or a micrometer at most. However, nanoscale is not just further miniaturization of the IoT. At this molecule-size, classical paradigms of communication may need to be completely reconsidered as problems and options arise. Instead of using electromagnetic communication principles like cable and radio, bio-inspired molecular communication offers a broad range of propagation principles differing in speed, accuracy, range, reliability and data capacity. For now, no communication type is preferred in the community and also communication hybrids may need to be considered. Even the nano machine itself can be fully biological, e.g., a cell. A networking concept needs to address this new kind of heterogeneous system.

3. FUNCTION CENTRIC NETWORKING

A system consisting of a BAN and an in-body nano network can be categorized into three layers.

Nano: The nano layer is the central part of the in-body network. It consists of nano machines deployed in the human body. The deployment areas and the density of nano machines can differ depending on the application. Nano

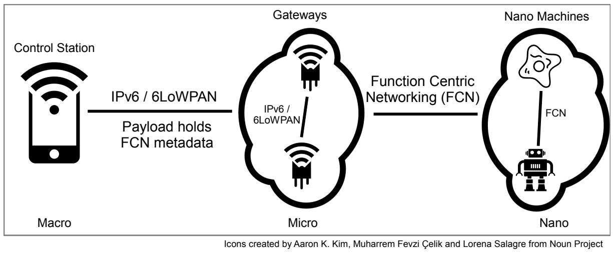

Figure 1: The three communication layer

machines themselves are either man-made nano-sized devices or biological constructs like natural or mutated cells with the ability to communicate [1].

Micro: The micro layer consists of micro-electro-mechanical devices (MEMS). They cover the largest part of the BAN and some provide gateway-functionality for the in-body nano network devices to enable micro-to-nano communication to collect data from or send orders to the nano layer.

Macro: Macro layer devices feature increased processing power and memory size, e.g. smartphones. They serve as a control-, analysis- and monotoring-system for the network. They collect data from and send requests or orders to the micro layer to be eventually forwarded to the nano layer.

While we already have solutions for macro-to-macro, macro-to-micro and micro-to-micro communication protocols, e.g. IPv6 or low overhead protocols like ZigBee and 6LoWPAN, we need to further investigate on the micro-to-nano and nano-to-nano communication aspects and propose Function Centric Networking (FCN) as a concept (see Figure 1).

FCN does not focus on individual nano machines but on their function and placement to allow on the fly replacement. While we do not care which nano sensor exactly is responsible for which measurement data, we still need context attached to the information, such as the approximate origin area of the data. It may be useful to detect increased concentrations of C-reactive protein and white blood cells as a marker of inflammation somewhere in the human body. It would be even better to know the location of the inflammation marked by the location with the highest raise in white blood cells. A reaction to an inflammation caused by bacterial infection would be to release antiobiotics, preferably only in the local area, which could be achieved by actor machines in the area containing encapsulated antibiotics. Therefore, we propose FCN addressing by a header consisting of the following parts:

Domain: The Domain is the combination of BAN and in-body network of a unique person.

Location: The location is a nameable part of the body or system, e.g. anatomical standards for the human body. The the accuracy of location-indication should be precise enough to fit the purpose of the message.

Function: The function addresses the desired type of nano machine. It can either indicate simple parameters like sensor or actor or more complex ones such as blood pressure detection or insulin release.

TTL: A time to live hop limit number for routing purposes.

ID: A unique ID serves as message identifier.

Segment: The segment holds information about the incrementally growing packet number.

The header information is used for pattern matching. A gateway or nano machine receiving a message compares domain, location and function information in the header with

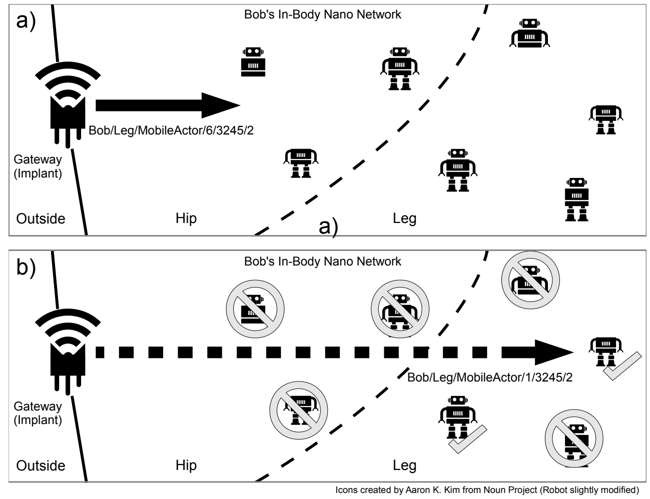

Figure 2: FCN communication example

it's own specifications. If the receiver is part of the right domain and location and can fulfill the function, it will accept the message and it's content for further processing. The pattern does not need to be fully used, fields can be left empty. Not setting a location would address nano machines in every body part. Not setting a function would lead to address all node types. Finally, setting neither location nor function creates a broadcast in the in-body nano network.

Figure 2 shows an example, where a gateway located at the hip in domain `Bob` inserts a packet with the header **a)** `Bob/Leg/MobileActor/6/3245/2` into the in-body nano network. The message addresses all nano machines in the `leg`, which are `mobile` and have `actor capabilities`, with a `hop limit of 6`, a message `ID of 3245` and `segment number 2`. While traversing through domain Bob **b)**, the hop limit decreases each time the message gets forwarded. Two nano machines matching the header pattern accept the message.

As future work we deal with this work-in-progress idea of FCN in more detail and provide evaluation through implementation and simulation using platforms like ns-3.

4. REFERENCES

[1] I. F. Akyildiz, F. Brunetti, and C. Blázquez. Nanonetworks: A New Communication Paradigm. *Elsevier Computer Networks*, 52:2260–2279, 2008.

[2] I. F. Akyildiz and J. M. Jornet. Electromagnetic wireless nanosensor networks. *Nano Communication Networks*, 1(1):3–19, Mar. 2010.

[3] F. Dressler and S. Fischer. Connecting In-Body Nano Communication with Body Area Networks: Challenges and Opportunities of the Internet of Nano Things. *Elsevier Nano Communication Networks*, 6:29–38, June 2015.

[4] J. E. Jang, S. N. Cha, Y. J. Choi, D. J. Kang, T. P. Butler, D. G. Hasko, J. E. Jung, J. M. Kim, and G. A. J. Amaratunga. Nanoscale memory cell based on a nanoelectromechanical switched capacitor. *Nature Nanotechnology*, 3(1):26–30, Dec. 2007.

[5] J. M. Jornet. A joint energy harvesting and consumption model for self-powered nano-devices in nanonetworks. In *IEEE International Conference on Communications (ICC 2012)*, Ottawa, Canada, June 2012. IEEE.