

Managing The Upcoming Ubiquitous Computing

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Abstract—The Internet of Things (IoT) is a promising theme of research. Covering subjects from micro-electronic to social sciences with a major field in computing, network and telecommunication. It is judged as the future of the today's Internet. The main idea is to benefit from an ambient intelligence instantiated by objects assisting humans in their daily tasks. One has already imagined use cases and challenging projects in separate areas, but challenge often means performances and requires expensive specific implementations or technologies.

Paradoxically, this technology fragmentation starves us from a rapid growth of the IoT whereas it prevents us to be flooded by the uncharacterized traffic it would generate [1]. Intersecting three domains of research that are Systems Monitoring and Management, Ubiquitous Computing and Cognitive Radio, we introduce our ongoing work on a new transversal use case called *Ubiquitous Cognitive Systems Management (UCSM)* to tackle this paradox and originate the chatty object concept.

I. INTRODUCTION

The IoT still misses its so necessary "killer application" which would provide us both a cheaper technology and an uncharacterized traffic. To trigger the popularity of the IoT while keeping an eye on what it could turn into, we introduce the *UCSM* use case. One can say that it is a monitoring and management application for the IoT which takes advantages from the tiniest nodes while considering their capabilities. This paper promotes a communication architecture dedicated to this use case. Therefore, the next section exposes the state of the art of three main concepts on which *UCSM* is built, while the third section gives an outlook of this paradigm which intends to make them converge. Section four presents our first research initiatives and our conclusion mentions future research steps.

II. A BRIEF REVIEW OF THREE PROMISING CONCEPTS

The novelty of our approach comes from the intersection of three main research fields. This section briefly presents their concepts and problematics. As our future Internet, the IoT is a system of nodes which needs to be monitored and managed. This latter point can only be achieved through node flexibility. As a result the IoT, systems management and software defined radio constitute the three mainstay of our research.

A. Ubiquitous Computing And The IoT

IoT is the generalization of Internet to objects and can be seen as the participation of wireless sensor and actuator networks (WSAN) and Radio-frequency identification (RFID) to the IPv6 network. We distinguish WSAN which organize

objects specifically designed to give intelligence to the environment, from RFID which most of the time only identifies basic objects. This distinction is illustrated by the classical vision in the Figure 1. WSAN offers new solutions for a variety of areas from environmental monitoring, to smart museum or gym [1]. Despite the fact that each of these areas has its own concerns and relies on specific solutions, alliances and work-groups pursue their efforts to suggest some standards that offer compromises. The main trade-off is between performance and longevity. Indeed, the possibility of an energetically autonomous "off-line" sensor is demonstrated in [2] while [3] shows that in typical sensor applications, the energy consumption is dominated by the nodes radio consumption. RFID is a much more mature technology which favors longevity and benefits from a myriad of standards. It has the main functionality of a small writable memory used as an electronic bar-code (tag) to identify anything, but can offer greater features as suggested by the WISP project [4]. The interrogated tag is passive and scavenges the energy from the radio wave of its reader to transmit the requested information up to the acceptable range of 15 meters [5] which can be reduced for privacy purposes in the case of Near Field Communication (NFC). We can infer from trade journal that this latter technology attracts leading companies and that a rapid convergence of standard will enable a worldwide usage of RFID. Apple already owns a patent to integrate RFID reader into their Touchscreen (US Patent 20090167699). On its side, Google recently acquired Motorola Mobility and is working on a NFC API for Android using state of the art NXP integrated circuits for their phones. This new type of communication and the way people will use it will definitely impact the way to manage network equipments.

B. System Monitoring And Management

To reach a certain level of quality, complex systems require tools that measure, monitor, and manage them. These tools are crucial to better understand and improve the global behavior of a system by identifying its internal mechanisms. When a system is managed or monitored, the common cycle is (1) measure and observe, (2) analyze to build a new set of knowledge, (3) make a decision. Social systems and communication networks are systems we both try to measure, understand and manage, their evolutions are co-dependent. In fact, there is only one step between them and it is called reality mining. This recent paradigm studies social systems thanks to communication networks [6] and it just misses its

counterpart which will make our future networks match our social systems and lifestyles. In the field of wired networking, some measurement and observation methods have emerged and are used by network operators [7]. The analysis task is even more and more efficiently automated to anticipate anomalies, attacks, events and their trends [8]. On the other hand for the upcoming IoT and its wireless communications, we still need knowledges and tools [1], [9].

C. The Cognitive Radio Paradigm

When Mitola introduced this paradigm ten years ago, he demonstrated by simulation the functioning of a cognitive software defined radio (SDR) [10]. In SDR, radio signals are processed by software running on CPU or reconfigurable devices. This approach has revolutionized radio-communications since the whole communication stack could be adaptive and not frozen by the hardware. Mitola also designed the Radio Knowledge Representation Language which formalizes the communication context. Based on this formalization he set up a cognition cycle to be implemented by nodes to improve their services. This concept opened an appealing field of research which is not yet realizable for average standards. Actually, the Achilles' heel is that the hardware chain limits software to low data rate protocols on reduced bandwidth. State of the art SDR are still experimental or integrate intermediate solutions with configurable devices [11].

III. UBIQUITOUS COGNITIVE SYSTEMS MANAGEMENT.

A. Making The Environment Chatty.

The UCSM address is to integrate contextual knowledges from "average" things in the unsupervised management of our future systems. The Internet of average things is often left aside because the added value for an average thing (furniture, mug, magazine) to be "connected" is not obvious. This common misconception is due to the literature which forces us to think that a thing would communicate only to improve its own services and functionalities. On the contrary, it can make sense if a thing also exchanges information to assist its neighbors. Thus, we can set forth the notion of *chatty thing*. When a thing is given a piece of information or context, it can adapt its behavior but it will mostly store then share appropriately this asset. Exchanging and inferring on the context gives to things the possibility (1) to best serve humans and (2) to improve their communication (including the context sharing itself) accordingly to their situation. This last point is our matter of concern. Context formalization should be evolutive and generic enough to take into account any kind of information from users (preferences, daily routines, interactions), to objects (resources and capabilities) to environment (time, place, communication protocols, waves propagation, regulation and standard).

As far as we know, nothing has been done to take into account the limitations of average things while exploiting the amount of information they could provide to network management. Given that an active protocol will suffer from battery problem for decades, we suggest to adopt a passive technology as the minimum universal way required to share

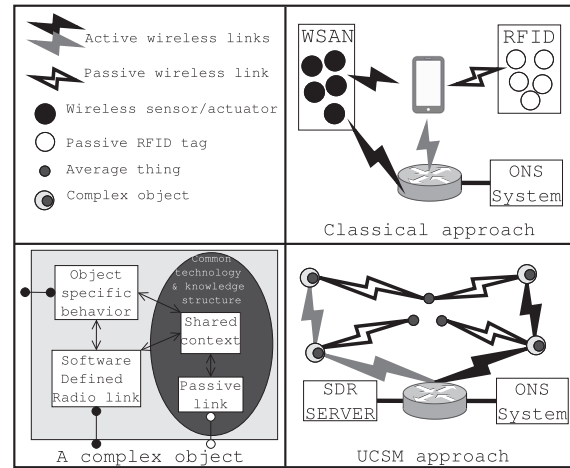


Fig. 1: On the top, the classic view of the IoT dissociates WSN and passive RFID. At the bottom, our vision includes complex objects and average things. They share a common ground to exchange on their context. In addition, complex objects implement an adapted software radio stack obtained from an SDR server. The specific object behavior adaptation remains to its designer and benefits from two service access points to exchange with the environment.

contextual information. Our paradigm merges every objects in the IoT, from average things to complex nodes (sensors, electronic devices or personal computer). Like illustrated in Figure 1 it provides them a framework to manage contextual information, "Average" things relay this information and make the environment chatty. This walk should both improve the functionality of products and their communication. Because improving the functionality of systems relatively to their context remains, devoted to their designers, our concern is to improve the communication in the upcoming IoT and adopt a cognitive radio approach. The value-added of ubiquity is that the cognitive work done by nodes is accumulated and kept by average things. Like Mark Weiser said in [12], information is everywhere. People do not always cogitate to get an information, they sometimes just read and communicate. Before dealing with intelligent things, let's make them chatty. Maybe some of the equipments, the most complex (gateway, computer and next smart-phones) will integrate cognitive engine with SDR one day, but not all of them, and at first they will be only configurable. For instance, many cognitive radio research work try to compute whole frequency spectrum, whereas it could be pertinent to ask the nearest object. This approach is used for Wifi and Bluetooth pairing using NFC. Thus, this kind of architecture should considerably improve Mitola cognition cycle since it allows evolved equipments to let some footprints of their work and help the less capable ones optimizing their communication.

B. Taking Benefit From The Environment.

When we are strolling in the street we are informed just by looking at traffic signs, promotional material, reminder, etc.,

so our smart-phone can do the same by reading passive RFID tag and start to put Weiser's word into action. Because the objects that surround us are most of the time the reflects of our lives, observing them should give us interesting benefits. This is the reason why social systems and the IoT should be considered together. The outcomes of *UCSM* are double. First it provides the necessary architecture to monitor and manage our future networks and second it offers our everyday life object the contextual information they need to behave as we want. The next three points give an insight into *UCSM* possible outcomes.

- *Behavioral guidelines*: Give advices and tips to devices on their system or network configuration (ie: silent mode, communication protocol stacks, local channel propagation, design for programmable hardware).
- *Traffic prediction and resource provisioning*: People generate different types of network traffic depending on their context and personality. Observing the context mutation for each user will allow operators and gateway to anticipate and predict the upcoming traffic.
- *Improve and multiply software assistants*: Cookies, preferences, history and localization had made their proof to improve information retrieval and intelligent software assistant like Siri and are usable by general electronic equipments. By simply scanning the surrounding objects a new dimension of context is given, this dimension would drastically augment the reality mining concept.
- *Social Studies*: In the case of the IoT, objects and people will learn to interact together. In this sense, monitoring objects might be compare to observing ourselves in a mirror. We believe that mining information on object's context will help researcher to understand the way we live and determine relation of cause and effect between phenomena or anticipate social trends.

C. Splitting the approach into three parts.

The presented concept refers to a complex management system. It can be split in several problematics which are of increasing difficulty:

- (a) **Management primitives in the IoT**: Assuming that a *universal chatty framework* is set up to monitor, manage and improve our communication network, the minimal requirement for this framework is to be at least configurable. Thus, this first problematic deals with the integration of atomic management commands in the existing standards for passive communications to reconfigure chatty things.
- (b) **Context formalization and its storage**: This second part deals with the possibilities to structure knowledge on the communication context in such a way that it could be safely spread and shared among chatty objects. The mains concern are to make the link between passive node capabilities (in terms of storage, and communication), context representation, users privacy and existing data standard for the IoT.
- (c) **Contextual machine learning system**: This third part studies the communication improvements that could

emerge from the processing of such contextual information. A knowledge discovery process will enrich the structure specified in (b) with inferences emphasizing the relationship between the contextual situation, network behavior and their impacts on the network performances. These relationships will then train a machine learning aiming to choose the network behavior that best matches the contextual situation with regard to the expected network performances. This predictive management approach would be applicable to any context sensitive system.

As a result, our first step has been to work on the integration of atomic management commands in current RFID standards, enabling the reconfiguration of the tiniest IoT nodes.

IV. INTEGRATE MANAGEMENT PRIMITIVES IN THE IoT.

A. RFID Standardization.

Classical RFID systems are basically composed of three segments which are tags (chatty things), readers (upcoming smart-phones) and a back-end information system to process the retrieved data (smart network equipments). Normative organizations like EPCGlobal, ISO/IEC and NFC Forum have fulfilled RFID systems with standards from radio signals to services discovery. The EPCGlobal structures them in Data standards and Interfaces standards, but we can also divide them into "*ontological*" standards and "*technical*" ones. The first will be considered later, to introduce the contextual formalization of *UCSM* in the IoT. The latter refers to the way manufacturers design their chips, and will induce the reconfiguration possibilities of chatty things. If standardization organisms tend to adopt a unique technology, industrial choice will mostly determine the de-facto standard, specifically in the case of the air Interface, where the ISO/IEC 15693 is a worldwide alternative for the 13,56Mhz ISM band and serves as a basis for other standards. We have then considered this standard to integrate management primitives in RFID.

B. Adaptation of an Air Interface Standard.

The ISO/IEC 15693 standard scope covers the nature of the electromagnetic field for power and communications, the physical characteristic of tags, and the medium access protocol (commands, anticollision methods). The communication is half-duplex and based on the exchange of a request from the reader and response(s) from tag(s). Each request or response are framed. A request consists of flags, commands, application data fields and CRC. Flags field determines the communication parameters of the responses (e.g. single/dual subcarrier, data rate), while the command fields details the action to perform (e.g. read, write, stay quiet). A response consists of flags, parameters depending on the command, application data and CRC. A simplified common procedure follows the next scheme:

- 1) The reader starts an inventory round.
- 2) Tags send-back their id by an anticollision procedure.
- 3) The reader has inventoried all reachable tags
- 4) The reader can send a request to a particular tag

The two mandatory commands are inventory and stay quiet, other commands (read, write, lock ...) are optional or proprietary. This protocol encourages manufacturer to part their tag design in three blocks which are respectively responsible for the analog interface and power management, the digital controller, and the user memory blocks (see fig 2). Thus, without manufacturer innovation, the tag communication is monolithic and gain few flexibility from the request's flags field, few command like the mandatory quiet command or the optional command Write AFI (Application Family Identifier).

C. The RFID Atomic Management Commands.

To offer a minimal management of the IoT tiniest node, we suggest to make them not smart, but obedient and configurable. We argue that the first step toward ambient intelligence is ambient obedience. Thereby, a solution to manage tag communication is to introduce horizontal cross-layering. This means to remotely configure communication layer from the reader because it has a better visibility of its neighborhood, and also the ability to compute and make pertinent decision. We have to admit that this strategy is near to be employed thanks to the flag field and the command cited above. This initiative needs improvement that goes through the use of optional commands, additional commands and specific tag design. We aim to offer readers the possibility to have management primitives or atomic management command to set and get (1) tag communication control registers, (2) tag communication status registers or (3) tag programmable logic design. Table I summarizes the required modification of [13] to enable our management primitives, while the figure 2 highlights the differences between a common design and a manageable design.

Optional commands to be used		
Code	name	Management Usage
'20'	Read single block	Get tags control/status register values.
'21'	Write single block	set tags control register values.
'23'	Read multiple block	Get tags configurable logic units.
'24'	Write multiple block	Configure tags logic units.
Additional management commands		
Code	name	Management Usage
'03'	Copy single block	store/load control register.
'04'	Copy multiple block	store/load configurable logic units.

TABLE I: Management Primitives RFID Commmands

Coupling this set of management primitives with a configurable design make the use of other optional commands such as Lock, Write AFI or Get System information obsolete since they can be modeled by read or write access to tag state. As illustrated in the figure 2, a configurable design let the reader access its state (assuming that locks are properly configured) because its state is included in the memory plan. The term state covers both functional registers of the tag (determining its behavior like a flag does) and configurable logic units which can be compared to configurable logic blocks in programmable devices (e.g. Field Programmable Gate/Analog Array). For instance in the case of RFID, these primitives could allow

readers to organize a deterministic TDMA between tags only by handling the register they use to determine their time slot. The use of these simple management primitives simplify the high level protocol implementation since its reduces the number of commands, in return the circuitry complexity increases because it involves programmable logic and non-volatile memory to configure the device. Nevertheless, we believe that our approach offers a feasible trade-off between read only tag and software defined radio.

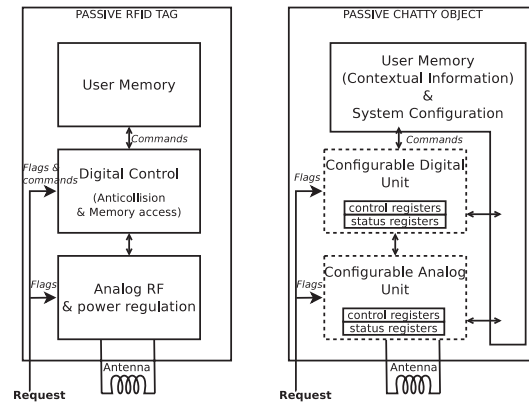


Fig. 2: Here are two simplified diagram block. On the left is a common RFID tag design. Its communication is driven by the flags field of the request and by others few specific commands. On the right, the behavior of a chatty object is configurable from the reader by accessing internal register or configuring programmable units.

V. CONCLUSION AND FUTURE WORK

In order to enable and control a rapid growth of the IoT, we introduced the UCSM transversal use case which takes part from three promising domains of research. This paradigm makes the environment chatty, leveraging contextual information to manage the IoT. After having exposed the main problematics of our concept, we have introduced the starting point of our ongoing research which is to adapt existing air interface protocol standards for HF RFID. The following step will be to handle the context formalization, by updating RKRL of [10] and offer to average things a tailored version. Finally one of the trickiest difficulty will come from the last problematic. It can be referred as a "bootstrapping" problem in which we have to consider network behaviors that do not exist yet and the associated issues. We intend to solve this starting by emulating the known behaviors in the IoT (ie: existing network behaviors and new behaviors to be introduced by our management framework).

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