International Journal of Pure and Applied Mathematics
Volume 117 No. 21 2017, 243-255
ISSN: 1311-8080 (printed version); ISSN: 1314-3395 (on-line version)
url: http://www.ijpam.eu
Special Issue
ijpam.eu

Being a Smart Sapien with Information Centric Networking and Cloud Computing

[1]Suresh Kumar Mandala, [2]Mahipal Reddy Pulyala and [3]Sanjay Pachouri
[1]Department of CSE,
Vaagdevi College of Engineering,
Bollikunta, Warangal, Telangana, India.
mandala.suresh83@gmail.com
[2]Department of CSE,
Vaagdevi College of Engineering,
Bollikunta, Warangal, Telangana, India.
mahipalreddy.pulyala@gmail.com
[3]Sunrise University,
Alwar, Rajasthan, India.
sanjay.pachauri@gmail.com

Abstract

Today, the radical Cloud of Things (CoT) paradigm, where Cloud and Internet of Things (IoT) technology are merged together, is foreseen as a promising enabler of many reallife utility eventualities, just like the clever domestic purposed. In this paper, we present a novel CoT platform that solves such demanding situations within the clever home domain via leveraging two groundbreaking standards Information Centric Networking (ICN) and Fog Computing. The idea, referred to as ICN- Smart-Sapiens, is a three-layered structure wherein an intermediate (Fog) layer, consisting of smart home servers (HSs), is added between the bodily international and the far off cloud, to aid real-time offerings and disguise the heterogeneity of IoT gadgets. As proof of concept, an experimental testbed is offered and some application examples are described to show off the superior capabilities of ICN-Smart-Sapiens.

1. Introduction

In the previous couple of years, the Internet of Things (IoT) paradigm swiftly received ground, with the aid of picturing novel ubiquitous computing scenarios wherein small every-day items become smart matters that measure, recognize, and adjust the surroundings.

Although cloud and IoT at the beginning evolved as separate research fields, they display many complementary components that encourage their integration [1]. Indeed, IoT gadgets – normally resource constrained - can benefit from the clearly limitless cloud/fog sources; while the cloud can use IoT to enlarge its scope by way of dealing with superior offerings in actual lifestyles environments [2]. Integrating cloud and IoT and making the resulting Cloud-of-Things (CoT) paradigm a fact is but no longer truthful. Several troubles are nonetheless debated, specially related to the dearth of widespread protocols, architectures and interfaces that could help the interconnection among heterogeneous smart gadgets and the cloud.

In addition, a innovative networking model referred to as Information Centric Networking (ICN) has these days attracted the eye of the research network working on information dissemination in specific destiny Internet domains, together with the smart home [3].This honestly simplifies data retrieval and network configuration, because ICN does not need mechanisms (e.G., DNS) to solve application-level names into network-layer addresses: a name may be without delay used on the network layer for content material/provider retrieval [4] [5]. In a few phrases, ICN well matches the information-centric pattern of many smart home packages (e.G., temperature or energy monitoring), which care about what data to retrieve (or service to request) instead of which node to hook up with. Examples of smooth-slate ICN smart home structures with real testbeds can be already found in literature [6], However, huge-scale deployments are presently infeasible, because the worldwide connectivity is IP-primarily based.

It is our convincement that the CoT paradigm can assist to fill this space, by way of making certain full reachability to information produced in ICN smart houses and, in addition, via imparting superior and efficient computing services. Our target in this paper is to combine ICN and CoT ideas in a common framework for smart homes which capitalizes the benefits of both paradigms. Our concept, known as ICN-Smart-Sapiens, consists of the subsequent revolutionary features:

1. According to the Fog Computing paradigm, ICN- Smart-Sapiens is organized as a 3-layered structure: an intermediate layer, such as smart home server(s) (HSs), is brought among the physical world and the remote cloud. Each HS can execute domestically complex obligations and control the home equipment, thus transferring a big a part of the (actual-time) computation as close as viable to the end devices (EDs).

2. The physical layer of ICN- Smart-Sapiens consists of ICN enabled EDs composing the smart home network. EDs act as home date producers or little service providers, they may be configured with significant, human-readable ICN names that "reproduce" their excessive-level functionalities. The HS retrieves data and requests offerings via ICN primitives.
3. To help heterogeneity, flexibility and extendibility, the HS hides the information of ICN EDs through a digital name-based representation and hosts a multi-agent software program application to monitor and manage the EDs.

The remaining paper is prepared as follows. Section II surveys current literature on CoT and ICN and motivates our work; Section III describes the ICN- Smart-Sapiens framework, whilst Section IV provides the applied testbed. Section V suggests some utility examples. Finally, Section VI concludes the paper.

2. Background and Motivation

1. The Cloud of Things Vision

The complexity and variety of IoT programs and the large range of heterogeneous elements concerned makes IoT information evaluation and operation making plans a totally difficult challenge.

Cloud computing can clear up many troubles associated with IoT records storage, computation, optimization and presentation. Moving the computation as near as viable to the physical assets implies (i) decreased network congestion and latency, on the grounds that big data transfers are prevented,(ii) removal of bottlenecks as a consequence of centralized computing,(iii) improved protection as data stays on the network aspect and the exposure to malicious assaults is constrained.

The framework deployed on this paper adopts the Fog Computing paradigm and introduces, between the physical international and the remote cloud, a disbursed intelligence layer that executes nearly all actual-time control tasks whereas the remote cloud degree stays in rate of non-actual-time tasks which include offline facts evaluation or presentation. Decentralization is acquired using a dispensed multi-agent gadget in which IoT application execution is finished through Agents' cooperation on the network side The allotted multi-agent machine exploits swarm intelligence standards [7].

2. Information Centric Networking

Today, there may be a selection of ICN architectures implementing name-primarily based communications [8]; among them, Named Data Networking (NDN) [9] is probably the most famous approach with a huge research community running in specific utility fields, consisting of the smart domestic.

Compared to IP based systems, NDN networking appears easier and nicely desirable to IoT packages [4].

Naming Contents, Services and Functionalities

Content names are hierarchical (now and again consumer-pleasant) and flexible, i.E., they are able to consist of a variable range of components with unbounded lengths. Although traditionally NDN names are associated with content material items, they may be used to become aware of additionally gadgets' functionalities and services. For instance, in [3], names describe sensing offerings, e.G., an Interest with name /sensing/temperature/bed room may be used to require the temperature of the bedroom in a smart home.

Easy and Strong Information Exchange

Communication is receiver-pushed; it consists of the change of named packets types, Interest and Data, used to request and transfer the content, respectively. Once the namespace is defined and every ED is configured with the names to apply, Interests can be sent to retrieve contents or request services, without the want of other facts, e.g., gadgets' community and port addresses.

Strong Protection

Security mechanisms are embedded via the manufacturer within the Data packet, for this reason assisting authentication and integrity directly at the community layer and permitting pervasive in community content material replication. Various cryptographic mechanisms can be supported, along with light-weight methods for IoT messages.

Support of Multi-Party Transport

NDN does now not require complex configurations to aid unicast or multicast communications: Interests are usually broadcasted over the wi-fi(wireless) medium, hence all of the nodes operating on the advertised call prefix are natively involved in the communication. This facilitates one-to-one and one-to-many (the so-known as multisource) interactions on the same time [10].

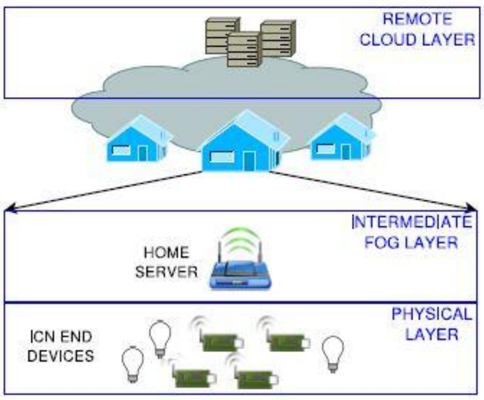

Figure 1: ICN-Smart Sapiens: Actors and Cloud/Fog/Physical Layers

Information-Centric Smart Houses

So far, one-of-a-kind factors of NDN-based smart home systems have been investigated. Security issues are analysed in [6] in which a initial lighting fixtures manage machine is designed. NDN names deal with all the system additives and get admission to control to fixture is performed via authorization guidelines. Attribute Based Encryption follows primitive security from untrusted users while data sharing in cloud [11]. All the aforementioned works don't forget local deployments with well-precise services and no interactions with the cloud or different remote entities over the Internet. In [10], remote interactions with the smart home are received through integrating NDN with the European Telecommunications Standards Institute (ETSI) M2M architecture. The suggestion guarantees international connectivity, however it does no longer combine with cloud programs, that could recognize effective smart domestic offerings.

In this paper, we installation a popular-motive smart domestic system in which NDN interacts with cloud/fog computing to gain of super, flexible offerings and global reachability. We attention on architectural elements to provide the overall picture of the machine and describe a few consultant programs implemented in our test bed.

3. The ICN-Smart-Sapiens Framework

As described in Fig.1, ICN-Smart Sapiens is prepared into three hierarchical layers with the intention to be detailed in the following.

The Physical ICN Layer

At the bottom of the framework, there may be the ICN Physical Layer. It consists of all the EDs, which installation sensing and automation tasks in the smart home. They are generally single function resource restrained gadgets, like temperature or movement sensors, or light actuators. EDs engage with the HS[1] thru the exchange of NDN Interest and Data packets. The major features of this deposit are briefly summarized in the following.

Naming layout. Each ED is configured on a properly-precise hierarchical namespace that describes the useful resource(s) it offers, i.E., sensing range(s), automation services. The namespace follows the three-important-additives consumer-friendly structure deployed in [3]. Therefore, we become aware of (i) the task type, sensing and action; (ii) the task subtype, e.G., energy, temperature for sensing tasks, light, heating for actuation duties; (iii) one or greater task attributes, e.G., the location of the EDs, e.G., bed room, kitchen.

Service models assist. Pull and push based communications are carried out. Pull primarily based transport follows the trendy NDN packets exchange: the HS sends Interests to acquire sensing data or to request actions. In both instances, Data packets are retrieved that include the sensed records or the result of the action execution, respectively. Vice versa, push based totally delivery is implemented thru Interest notifications, i.e., a unique Interest packet wherein the ultimate element of the hierarchical name is used to carry the data [5]. This is a viable solution in presence of IoT Data, which can be usually brief. In our layout, the HS is configured to just accept Interest notifications from the EDs, extract the content material from the name field and send a Data packet to renowned the reception.

Group-based totally communications. Thanks to the hierarchical namespace, multi-source communications also are enabled, in which a single Interest is used to concurrently query groups of EDs sharing a few a part of the identical namespace, e.G., the Interest /sensing/temperature requests the temperature data to each temperature sensor of the residence.

The Intermediate Fog Layer

The Intermediate Fog Layer includes the HSs, which enforce the software application logics to display and control the house in line with (i) user preferences, (ii) inputs from stakeholders, e.g., service providers and regulation entities, (iii) dynamic context-related elements e.g., the strength market price. The HS interacts with the EDs, thru ICN, and with the remote cloud, through trendy Internet connectivity.

In addition to the software for NDN communications, each HS hosts the multi-agent utility and the virtual items abstraction to carry out Fog offerings.

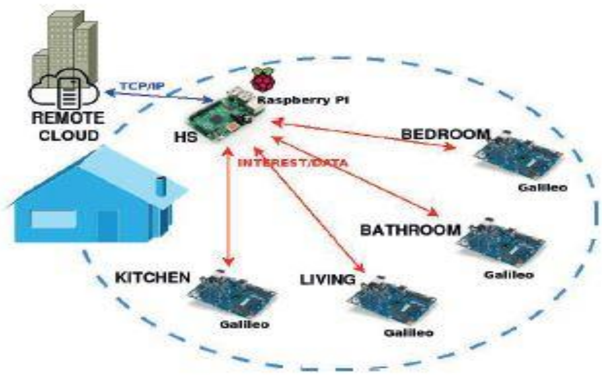

Figure 2: ICN-Smart Sapiens: Testbed

To get admission to statistics via the VO abstraction, VOs and Agents need to be co-located in the identical HS. Therefore, instead of shifting data to a significant processing unit, ICN-Smart-Sapiens transfers techniques (Agents) in the direction of the EDs. As a consequence, less data wishes to be transferred toward faraway hosts; local get admission to and computation are fostered with the intention to gain appropriate overall performance (i.E., low latency, real-time offerings) and scalability (i.E., Fog nodes are geographically disbursed, in comparison to centralized Cloud).

C. The Remote Cloud Layer

The Remote Layer includes a remote Cloud platform, which addresses all those activities that cannot be accomplished by using the HSs, e.G., responsibilities requiring excessive computational sources or lengthy-time period historic records. The data evaluation carried out through the Cloud may be used for one-of-a-kind functions, together with (i) to optimize the Agents' operations and their behaviour, (ii) to guide the demands of external customer applications, e.G., collected statistics can be utilized by power provider organizations for dependable forecasting

4. Test Bed Deployment

As proof of concept of the envisioned framework, we built a demonstrator with low-fee off-the-shelf devices that reproduce an ICN clever domestic community with CoT talents, see Fig.2.

Devices Features

The HS is carried out over a Raspberry Pi tool which is a single-board pc equipped with A SD memory card, an Ethernet interface, and a IEEE 802.11g wireless interface for wi-fi communications with the EDs. As operating system we selected Raspbian a unfastened distribution of Debian optimised for the Raspberry Pi hardware. EDs are distinct kinds of sensors and actuators (e.g., temperature and motion sensors, light actuators) connected to Intel Galileo forums Galileo is the first 32-bit System-On-A-Chip (SoC) microcontroller board designed to be hardware and software program pin-compatible with Arduino shields. Therefore, it's miles a flexible and value-effective answer, which could interact with any variety of sensors/actuators and, at the identical time, aid Linux-based totally operating structures. We use 4 Galileo boards in our testbed, each one symbolically located in a one-of-a-kind room of the smart home (bedroom, kitchen, bathroom, Living) to display and manage it. Each room may be partitioned in or greater zones, each one recognized by using a number of, e.G., both the bed room and the kitchen have two zones, zone1 and zone2. Each Galileo is one-hop away from the HS and uses IEEE 802.11g shields for wi-fi communications with it. As OS, we installed Yocto an open-supply whole embedded Linux improvement environment. Finally, a workstation is used to host the remote cloud programs. It is connected to the campus network and communicates with the HS through general TCP/IP protocol.

ICN Implementation

To permit ICN communications between the Raspberry Pi and the Galileo forums, the CCN-Lite software has been decided on. It is a light-weight implementation of the CCNx/NDNx protocols that incorporates the absolutely permissive ISC license and deploys the standard (static) content retrieval, primarily based on the (single) Interest - (unmarried) Data transer. The tiny code base has been prolonged to deal with the actual-time production of sensing facts and automation offerings from the EDs. Specifically, every Galileo runs a CCNLite example configured with a set of working name prefixes (e.G., the Galileo inside the bedroom works at the prefixes.

/sensing/temperature/bedroom/{range1,range2},/movement/light/ on/off/increase/lower/bedroom/{range1,range2}

When the Galileo receives an Interest for a sensing or an automation venture, the call lookup is finished. If an identical is discovered, it launches the correspondent sketch program that drives the execution of the project from the ED(s). Finally, it includes the end result right into a Data packet that is sent back to the Raspberry Pi. Important modifications on CCN-Lite had been also accomplished to aid the functions described in Section III-A (i.E., Interest notification, multi-source delivery).

Smart-Sapiens Core Components Implementation

The Raspberry Pi hosts the Smart-Sapiens core components running on the Fog Layer, which encompass: (i) the Agent Server, a runtime environment for Agents execution and (ii) the VO Container, an entity that manages the VOs. Each VO is carried out as a group of VO functionalities, which may be defined thru the interface VO Container. Virtual Object Functionality. This latter includes a set of techniques, which may be described to manipulate and screen the ICN EDs. For instance, the test approach returns sensing information, the acting technique an automation task, the add Stream Listener Technique returns asynchronous sensing notification. Agents use such methods to access the ED assets in a homogeneous fashion and exchange information among each different through asynchronous messaging. In addition, by means of defining VOContainer. Rule gadgets, boolean guidelines may be finalized to allow Agents subscribe to precise occasions (e.G., while the sensed temperature is lower then a threshold, or when the power intake reaches a predefined degree), and perform complex application logics.

ICN-VO Interface

Thanks to using ICN name-based totally communiqué, the implementation of the interface among the Physical Layer and the VO abstraction is extremely facilitated. Each physical tool may be accessed by directly the usage of the call of its resources, without the want of does not forget network addresses, port numbers or maybe layer-2 addresses. The Raspberry Pi hosts a hard and fast of C programs (referred to as ICN ship/recv exercises) that take as enter ICN names and allow shipping Interests and extracting information from Data packets or from Interest notifications2. ICN ship/recv routines are invoked, controlled and manipulated from the VOContainer. VirtualObjectFunctionality interface.

5. Applications Example

To better recognize the behaviour of ICN-iSapiens from a realistic perspective, we describe two packages based totally on a set of tracking and controlling obligations deployed within the clever home: (i) an electricity-saving light control software, and (ii) a clever door lock utility. As shown in Fig. 2, the clever domestic consists of 4 rooms, each one instrumented with the aid of the following sensors for the mild management utility: (i) sensors detecting whilst a person enters or leaves a room, (ii) proximity sensors detecting the presence of humans in each zone of the room, (iii) illuminance sensors. In addition, adjustable brightness lights are covered in every zone of each room.

The smart door lock utility is primarily based on a sensor, embedded on the principle door, to hit upon beginning, last and front events. An actuator instead manages the opening and closing of the door. All the referred to gadgets paintings on a selected ICN namespace that identifies their functionalities (see Table I, II for a few name examples).

ICN VO layout. Each VO abstracts and wraps a sure variety of sensors and/or actuators. Table I suggests the functionalities exposed via the Virtual Kitchen Light, collectively with the correspondent ICN names. Each capability of the digital mild object is parametric: the area parameter specifies which area of the room is referred. Similarly, a Virtual Home Door item is defined, as proven in Table II. Agents design. The target of the mild control software is to adjust the lights in every room on the basis of people presence/actions and the present day illuminance. This [2]We extended the ccn-lite-peek software, already available within the CCN-Lite package deal, to allow the HS send Interests.

Common sense is applied in the LightAgent. When the application is energetic, the HS periodically sends Interest packets wearing the relative names, e.G., an Interest with name sensing/illuminance/ kitchen/zone1 is issued to question the illuminance sensor in the zone1 of the kitchen. At the better layer, the Virtual Kitchen Light collects the sensed values and makes them to be had to the LightAgent.

A set of easy rules are described to support the application good judgment. In this case, the VO appearing approach is invoked and then the real transfer-on command is despatched in an Interest packet, e.g., with name movement/mild/on/kitchen/zone1.

So a long way, by using relating to our testbed scenario, we considered the special case of a unmarried HS in the smart home, therefore ICN EDs constantly speak with the node wherein all the VOs are deployed. Figure 3 shows the undertaking to three HSs in the big villa topology. Agents without reference to any physical component may be placed everywhere, even in a faraway cloud node.

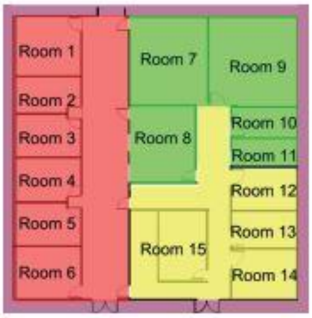

Figure 3: Rooms Assignment to HSs in a Large Villa Topology. Each Different Color Identifies a Different HS

A device component known as Deployer is in charge to load the Agents upon the Agent Servers, to set up acquaintance relationships among them and to start the utility. Acquaintance relationships are vital to let Agents engage with every different. For instance, consider a Heating Agent, which manages the heating system by means of considering the current sensed temperature and the number of human beings inside the residence.

TABLE I: Kitchen Virtual Light.

Functionality	Type	Description	ICN Namespace
near people	Sensing	number of people in the zone	/sensing/people/kitchen/{zone1,zone2}
increase_light	Action	increase light brightness in the zone	/action/light/increase/kitchen/{zone1,zone2}
decrease_light	Action	decrease light brightness in the zone	/action/light/decrease/kitchen/{zone1,zone2}
light_off	Action	set off light in the zone	/action/light/off/kitchen/{zone1,zone2}
light_on	Action	set on light in the zone	/action/light/on/kitchen/{zone1,zone2}
illuminance	Sensing	illuminance in the zone	/sensing/illuminance/kitchen/{zone1,zone2}

TABLE II: Virtual Home Door.

Functionality	Type	Description	ICN Namespace
locking status	Sensing	Boolean (true if the door is closed, false if the door is open)	sensing/door/locking{true, false}
entrance status	Sensing	Integer (Counting the number of people inside the house. The counter increases when a person enters the house, decreases when a person leaves)	sensing/door/entrance{true, false}
open	Acting	Open the door	acting/door/open
close	Acting	Close the door	acting/door/close

When all of the human beings go away and the door is locked, the HeatingAgent have to flip off the system. After loading each Agent in the right area, the Deployersends acquaintance messages to the HeatingAgent in order to allow it recognize the DoorAgent. Afterwards, the HeatingAgent sends an acquaintance message to the DoorAgent so as to be regarded via it. Once the deployment phase is finished, the utility execution can start. When everybody leaves the residence, the DoorAgent locks the door and sends a message to the HeatingAgent, for you to turn off the heating device.

6. Conclusion

In this paper, a singular CoT platform for Cloud -more suitable clever smart services, referred to as ICN-Smart Sapiens, has been described. The thought leverages the revolutionary Fog Computing and ICN paradigms to set up smart tracking and manipulate applications in an green and powerful fashion.

References

[1] Botta A., De Donato W., Persico V., Pescapé A., Integration of cloud computing and internet of things: a survey, Future Generation Computer Systems (2016), 684-700.

[2] Petrolo R., Loscri V., Mitton N., Towards a smart city based on cloud of things, Proceedings of the ACM international workshop on Wireless and mobile technologies for smart cities (2014), 61-66.

[3] Amadeo M., Campolo C., Iera A., Molinaro A., Information Centric Networking in IoT scenarios: The case of a smart home, In IEEE ICC (2015), 648–653.

[4] Panchumarthi G.P., Surendar A., A review article on Fin-FET based self-checking full adders, Journal of Advanced Research in Dynamical and Control Systems 9(4) (2017), 1-8.

[5] Priyanka Reddy G.S., Surendar A., A review article on performance comparison of CNTFET based full adders, Journal of Advanced Research in Dynamical and Control Systems 9(4) (2017), 9-20.

[6] Amadeo M., Information-Centric Networking for the Internet of Things: Challenges and Opportunities, IEEE Network 30(2) (2016), 92–100.

[7] Burke J., Gasti P., Nathan N., Tsudik G., Securing Instrumented Environments over Content-Centric Networking: the Case of Lighting Control and NDN, IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS) (2013), 394–398.

[8] Cicirelli F., Forestiero A., Giordano A., Mastroianni C., Transparent and efficient parallelization of swarm algorithms, ACM Transactions on Autonomous and Adaptive Systems 11(2) (2016).

[9] Marica A., IEEE 14th International Conference on Networking, Sensing and Control (ICNSC) (2017), 245–250.

[10] Zhang L., Named Data Networking, ACM SIGCOMM Computer Communication Review 44(3) (2014), 66–73.

[11] Amadeo M., Briante O., Campolo C., Molinaro A., Ruggeri G., Information-centric networking for M2M communications: Design and deployment, Computer Communications (2016), 89-90.

[12] Vurukonda, Naresh, Thirumala Rao B., Sabe Efficient and Scalable Filtered Access Control In Distributed Cloud Data Storage, Journal of Theoretical & Applied Information Technology 95(6) (2017).

[13] Burke J., Gasti P., Nathan N., Tsudik G., Secure sensing over named data networking, Network Computing and Applications (NCA) (2014), 175–180.