Context-Aware Mobility Based on π-Calculus in Internet of Thing: A Survey

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Abstract. Nowadays, the computing is becoming faster and faster to support very other scientific areas. Internet of Thing (IoT) is taking much advantage from it. At the beginning of IoT, the static things joined in IoT such as: cameras, sensors, and vending machines. Due to the progress of computing science, IoT is expanding on mobile things such as cars, patients, cellphones and other mobile things for traffic controlling, health care, or getting information. The network of mobile things is called as Internet of Mobile Things (IoMT). There are some problems to be solved in IoMT as: Security and Privacy, Mobile Data Collection and Analysis. The data collected from the mobile things can help to improve the security and privacy better, or using for special purposes. To get the data of mobile things, moved from one cluster to another one, we need an algorithm to solve following things: mobility of mobile nodes, and changing in number of the mobile nodes. The pi-calculus is one solution for this problem. Pi-calculus is introduced by Milner as a formal language for modeling and verifying system requirements. In this paper, a survey is performed on pi-calculus for IoMT, and other related calculi.

Keywords: IoT · IoMT · Pi-calculus

1 Intoduction

At the first days of IoT, the static things are connected to Internet by sensors to collect data for specific purposes. The data is analysed to get information from it. This process is context-aware. The context-awareness, used for getting information of the things in IoT, uses to improve the authentication and privacy in IoT. Nowadays, not only the static things join in the internet, but also

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the mobile things connect to IoT by sensor controlled by android system to send WiFi signal to the data centre [3–5,7–9]. The problem of mobile things is moving from one cluster to another. The mobility in IoMT relates to some problems, needed to solve in IoMT, as mobile data collection, mobile data analysis, energy management, and security and privacy [1]. In the paper [1], the process of IoMT introduces in the detail. First, IoMT need a MobilityFirst framework with protocol to support the communication among mobile nodes. The mobile node is applied Ipv4 or updated to IPv6 with 128 bits or 16 bytes length size of address to routing in Wireless sensor networks (WSNs). Each static node has static IP to communicate together in WSNs, but the mobile node is not. The mobile nodes move from one cluster to another one. That means the IP address must be changed. The IP address must be cleaned for next users when it moves out of the cluster. Besides, the number of mobile nodes also change in WSNs. To solve this problem, Milner introduces pi-calculus as a formal language for modeling and verifying system requirements. This paper has three parts. The first section is The calculus for the IoT (CaIT). The second section is survey on pi-calculus with some research work for IoT. The last section is survey on other calculi that are applied in IoT and IoMT to solve dynamic mathematics.

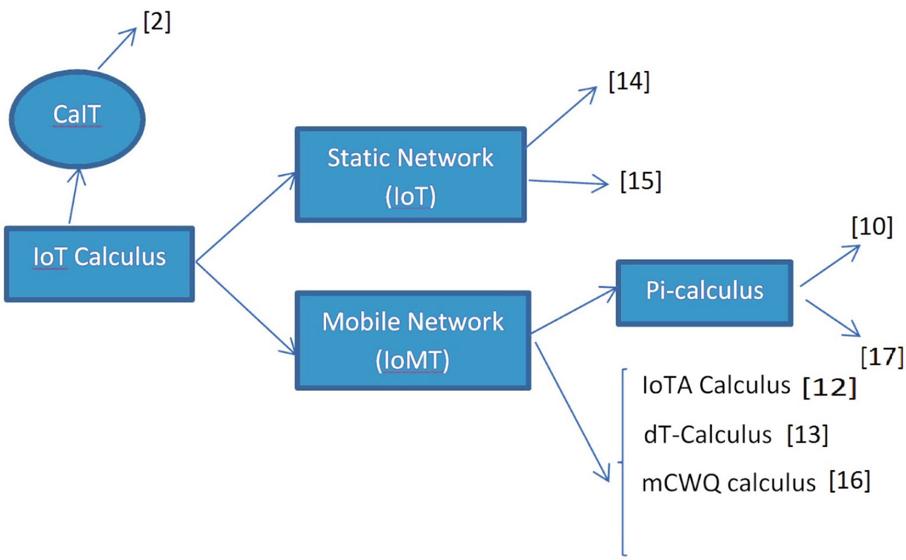

Fig. 1. The total view of calculi on survey

Figure 1 is total view of calculi on survey. The calculi are divided in two branches: Static Network (IoT) and Mobile Network (IoMT) with the papers listed in references section.

2 Calculus for IoT

The calculus for the IoT (CaIT) has two level structures: low level for processes, higher level for network of smart devices. Some example syntax of CaIT is showed in the Fig. 2

$$
\begin{array}{lcll}
\textit{Network:} & & & \\
M, N & ::= & \mathbf{0} & \text{empty network} \\
 & \mid & n[\mathcal{I} \bowtie P]_h^{\mu} & \text{node/device} \\
 & \mid & M \mid N & \text{network composition} \\
 & \mid & (\boldsymbol{\nu} c)M & \text{channel restriction} \\
\textit{Process:} & & & \\
P, Q & ::= & \mathsf{nil} & \text{termination} \\
 & \mid & \rho.P & \text{prefixing} \\
 & \mid & P \mid Q & \text{parallel composition} \\
 & \mid & \lfloor \pi.P \rfloor Q & \text{communication with timeout} \\
 & \mid & [b]P;Q & \text{conditional} \\
 & \mid & X & \text{process variable} \\
 & \mid & \mathsf{fix}\, X.P & \text{recursion}
\end{array}
$$

Fig. 2. Some syntax of CaIT in [2] with n, m as nodes/devices; c,g for channels; h,k for (physical) locations.

CaIT is just simple reduction semantics to model the dynamics of systems in isolation based on the IoT paradigm. To interact IoT systems with the environment, it need to be emphasized this interaction. Authors in [2] have improved it to define a labelled bisimilarity. However, CaIT is only a calculus based on the IoT paradigm, and differs to IoT-calculus. In the paper [6], authors yield at the first process calculus for IoT systems to capture the interaction between sensors, actuators and computing processes. Both sensors and actuators in IoT are under the control of a single entity. This gives out the problem of security. Authors in the paper [14] proposed a calculus for wireless-based cyber- physical systems (CPS), allowed modeling and reasoning about cryptographic primitives, together with explicit notions of communication failure and unwanted communication. Main purpose of CPS is faithful representation denial-of-service. However, in the paper [15], X. Wu pointed out the calculus does not provide a notion of network topology, local broadcast and behavioural equivalence. The distinction between physical components (sensor and actuators) and logical ones (processes) is not clear. Finally, the paper in [15] (CWQ Calculus) introduce a static network topology and enrich the theory with a harmony theorem. The static network just only includes the static nodes. To more understanding on it, the smart house is an example. Everything is put sensors inside such as: television, lamp, air-controller, doors to control via smartphone, or to get information and save them in the data centre for other purposes. However, the mobile things are more difficult. They are mobile nodes, such as cars, patients, that move from one cluster to another one. When they drop out, the IP addresses are cleaned for next users. Besides, the mobile node need to be charged, or turned off (if it in inactive mode) to save the energy. This is dynamic mathematics in IoMT. We need another calculus to meet these standards as pi-calculus for example. The next section in this paper will review pi-calculus in more detail. The final section is other calculi on survey.

3 Pi-calculus for IoMT

In the paper [11], pi-calculus has two roles as modeling for networking and sending messages from site to side, or model of computation by Milner. Modeling for networking describes the networking to be how to synchronize and pass message between various activities. The model also describes the interaction inside. The pi-calculus has an advantage to solve the problems in concurrent and dynamic systems. The mobile nodes require a rapid identification authentication and privacy protection. They need a protocol to solve the problem: joining in a new cluster. In the paper [10], Jingjun Miao introduces a new protocol based on pi-calculus that can resist replay attack, eavesdropping attack, and tracking or location privacy attack. The protocol also confirms the ability to satisfy two privacy protection properties known as untraceability and forward privacy. The authors yield out the new calculus called the applied pi-calculus as language for describing concurrent processes and their interaction. Pi-calculus is extended by adding possibility to model cryptographic primitives through a signature and an equation theory. To understand it in more detail, the following Table 1 shows it.

In table, there are standard primitives from the pi-calculus together with ifthen-else and the possibility to output terms. This syntax is used to model the protocol. The plain processes and extended processes use for one side to execute a complete session when the protocol is running communication. In the paper, the security and privacy of the protocol is “no one knows content inside the data, and no one knows where it is sent to”. This is called untraceability. There are a lot of authentication protocols with privacy but they are too heavy computation and communication, and are not suit for IoT. The authors introduce rapid authentication protocol in the applied pi-calculus. It is convenient protocol in the kind of environment of IoT. The mobile node is authenticated by the cluster node through this protocol. This protocol is not only simple authentication but also realize credible transmission of mobile node among clusters. In addition, the protocol can resist replay attack, eavesdropping attack and tracking or location privacy attack. However, the authors still do not have the solution for context-awareness (to improve the authentication and privacy, or use for specific

Table 1. The syntax of applied pi-calculus

Symbol	Meaning
P, Q, R :: =	Plain processes
0	Null processes
P|Q	Parallel composition
!P	Replication
vn.P	Restriction
If M = N then P else Q	Conditional
u(x).P	Message input
$\bar{u}$ <N>.P	Message output
A, B, C ::=	Extented processes
P	Plain processes
A|B	Parallel composition
vn.A	Name restriction
vx.A	Variable restriction
{M/x}	Active substitution

purposes), and mobility (moving of mobile nodes) in IoMT. In the below layers of mobile nodes network, the paper [17] yields out multi pi-calculus to modeling cognitive model for ad hoc network. The ad hoc network is a multi-hop temporary autonomous network system for mobile node system without fixed base station. It has no centre, and acts as self-organization, multi-hop routing and dynamic network topology structure. The multi pi-calculus work is used in many layers of the ad hoc network such as: access cognition layer, service agent cognition layer, service cognition layer. The multi pi-calculus provides powerful formal tool to contribute to accurately qualitative and quantitative analysis, and reasonable judgment basis for ad hoc network cognitive performance evaluation. In the same with the paper [10], the paper [17] still focuses on cognitive problem of the mobile nodes. Both of them need integrated more the solutions for the context-aware and mobility of the mobile nodes.

4 Other Calculi (Based on Pi-calculus)

In Wireless Sensor Network (WSNs), the important thing is node mobility that yields out abnormalities and decreasing the quality of service. In the paper [16], the authors give out the solution known as mCWQ calculus (CWQ calculus with mobility). The calculus shows how to capture the feature of node mobility and increase the quality of the communication. The calculus is based on Hoare Logic to describe the timing of observable actions. The mobility models are random motion of each entity node. The mCWQ calculus can be used for specifying the movement trajectory models of entity mobility of the nodes. The mCWQ updates the new nodes for mobility function. The mobility function changes at any time. We can refer to the syntax of mCWQ in the Fig. 3

Processes

$$P ::= nil \mid Act.P \mid [t_1 = t_2]P_1, P_2 \mid P_1 \parallel P_2 \mid P_1 + P_2 \mid$$
$$\textbf{case } e \textbf{ of some}(y) : P_1 \textbf{ else } P_2$$
$$Act ::= c!v \mid \sigma \mid b$$
$$b ::= c?x \mid \&_q(b_1, ..., b_n)$$
$$t ::= c \mid v \mid y$$
$$e ::= x \mid \textbf{some}(t) \mid \textbf{none}$$

Networks:

$$N ::= 0 \mid n[P]_T^f \mid N_1 \parallel N_2$$

Function:

$$F ::= D(\overrightarrow{l_1}, \overrightarrow{l_2})$$

Fig. 3. The syntax of mCWQ calculus

In the mCWQ calculus, the messages are passed between nodes. Channels are asynchronous, so the sender does not need to wait for the receiver, but send immediately. Result is the message to be able to be lost if there is no receiver, because of no buffering of message. The receiver still wait until message is available. The mCQW calculus not only has ability to capture the features of mobility, local broadcast, time delay and quality of WSNs, but also is provided a set of proof rules to verify the correctness of WSNs. The paper solves the mobility problem in IoMT, but still remains the context-aware problem in IoMT. Besides, in the paper [1], the mobility of IoMT needs to turn off the mobile node to save energy. That means the number of mobile nodes are changeable. The mCQW calculus is good in capturing the feature of node mobility and increasing the quality of the communication, but still does not have the solution for changing the number of mobile nodes. Other calculi, applied in IoT, are IoTA calculus [12] and dT-calculus [13]. IoTA is the first calculus for the domain of home automation. Home automation means being able to control the devices such as: lights, locks, refrigerators, televisions, and cameras. While as, dT-calculus is a formal method to specify distributed mobile real-time IoT system. In this paper, authors review more calculus as Time pi-calculus and d-Calculus. Time pi-calculus has capability to specify time properties, but lack of direct specifying both execution time of action and mobility of process itself such as: ready time, timeout, execution time, and deadline.

5 Summary and Development Direction

The progress of computing helps the sciences better. The IoT, especially IoMT, has taken advantage from the computing so much. In the paper [1], we make a survey on context-aware and mobility in IoT. The researches just focus on the protocols for security and privacy problem in IoT communication. It is need a calculus to solve the dynamic mathematics in IoMT in which there are moving of the mobile node from this cluster to another one, or changing of the number of mobile nodes. First, there is the calculus for IoT called CaIT. The CaIT is based on IoT paradigm to interact IoT systems with environment. The CaIT differs to IoT-calculus. The IoT-calculus branch divides in two branches. One is static network with the papers [14] and [15]. The other one is pi-calculus with the paper [10] and [17]. Besides, other calculi, based on pi-calculus, include IoTA calculus [12], dT-calculus [13], and mCWQ [16]. The static network is static nodes network without moving, so the researches on this field just focus on routing, communication between nodes, security, privacy and cognition. In the paper [14], authors have proposed applied quality calculus for wireless-based cyber-physical systems (CPS), allowed modeling and reasoning about cryptographic primitives. In the paper [15], CWQ calculus is used in static network topology. In IoMT, the nodes move from one cluster to another one, so it needs a new calculus to solve the mobility problem and changing number of mobile nodes. In the paper [10], authors introduce Applied Quality Calculus that focuses on modeling networking and sending messages from site to site to resist replay attack, eavesdropping attack, and tracking or location privacy attack. In the paper [17], authors yield out multi pi-calculus to modeling cognitive model for Ad hoc network. Both of them do not have any solution for the mobility of IoMT. That means the mobile node can be dropped when it move out of the cluster. Its IP address needs to be cleaned for next users. We need a calculus to capture the moving of the mobile nodes. The solution of this problem is yield out in the paper [16]. The mCQW in the paper [16] is a calculus with mobility that shows how to capture the feature of node mobility and increase the quality of the communication. However, there is a problem that needs to be solved is changing of the number of mobile nodes (inactive nodes turn off). Besides, there are some other calculi such as: IoTA (for domain of home automation), dT-calculus (specify distributed mobile real-time IoT system). As the survey of the paper [1], context-awareness is used to improve the security and privacy, or is used for specific purposes. So, the future researches are on combining of context-awareness and mobility (changing number of mobile nodes and moving of mobile nodes).

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