

A Pervasive Computing Model of Internet of Things based on Computing Area Network

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Abstract— Pervasive computing is considered as a new computing model providing computing and services, representing developing direction of the coming generation of information. The emergence of The Network of Things makes changes to the environment of pervasive computing, and the internet of users expanded the spaces and information. It also sets an even higher demand on pervasive computing and upgrade support service and promotes pervasive computing becoming the basic computing model of internet of things. Basing on the new hierarchy computing model of pervasive computing, a new control system model of computing area network (called CAN-CSM) is presented in this paper, regarding as core implement and virtual computing nodes. The internet of things is composition of a large number of CAN. The main function of CAN is reconstruction of virtual equipments dynamically, and it can describes ability, execute estimation, delivering work, providing Data+Code+Status service migrations. In the context of internet of things, things part of "computing area network" can be seen as an abstract "reconfigurable" computer, which is a great innovative way.

Index Terms—Internet of Things, Pervasive Computing, computing area network, Control System Model, DCS

I. INTRODUCTION

In 1991, PARC Computer Science Laboratory of Mark Weiser wrote "The Computer for the 21st Century" [1], this article point out that pervasive computing will be the future of main computing model. With the field of pervasive computing as domestic and foreign

academic and industrial research in the field becoming hot spots and main direction, it will transparently provide people with digital information services anytime and anywhere. Pervasive computing has transparent, dynamic and diversity features, it will produce effect on the development of computer technology and applications.

In 1999, EPC global and automatic identification lab at MIT put forward internet of things [2], that is to say, all the things in the world are connected to internet and the information can be exchanged. At the same time, they also point out the development direction of internet. in 2005, Tunis World Summit on the Information Society entitled "Internet of Things," the report predicts that the information exchange among things and become the "internet of things" is no longer out of reach. The internet is the future of the internet of things, called big things. The appearance of internet of things have enabled pervasive computing environment changes, and profoundly contributed to pervasive computing research and development

Internet of Things is assembled by traditional computer, information on new equipment and new computing devices connected network. In the environment of pervasive computing of internet things, all the things are connected as network, and the computing environment has following features, distribution, heterogeneity and dynamic nature. How to implement device manage, information manage, control and estimation? A control system model of computing area network (CAN-CSM) is presented in this paper. In this method, the WAN of

internet of things is divide into lots of computing area network, and each computing area network for the smaller size of the computing device modules build a virtual computing environment and all the network are connected by wireless. CAN provides dynamic re-management mechanism, so that the device can dynamically join and exit the cell area network computing to implement dynamical reconstruction equipment supply ability description, matching and search mechanism and also provide equipment; management system and implementation of assessment tasks distribution mechanism.

II. PERVASIVE COMPUTING SERVICES

The focus of traditional ubiquitous computing services is put on the: service discovery, service migration, context-aware [3] , however, in the ubiquitous computing environment of Internet of Things, it should include Data (data) ,Code (Code) and Status (status). The nature of the migration service should also transfer data, Code and Status, that is to say, "DCS" should move in the information space according to require-ment to meet the material requirements of networked computing environment.

To address the problem of Migration services and reflects its "computing adapt to people," in other word, the core of the computing tasks that allow users in the physical space with the displacement in the information space of the corresponding migration, perform the task associated with application state, properties and scene information simultaneously transferred. And it can also adapt to new scenarios available computing resources, and users can continue in the new location before moving computing tasks. As a result, the following characters are achieved: distributed nature: the huge information resources are distributed on the hosts around the world; heterogeneity: hardware, operating system, web forms, data formats vary; dynamic: the amount of resources, types and effective of changing.

Pervasive computing research is currently lack of support of traditional "Data+Code+Status" scheme for the implementation of integration [4], in particular the lack of ability of transference of DCS among difference equipments in ubiquitous networking and computing environment. In the environment, ubiquitous computing needs a new computing model to support the DCS migration and enforcement mechanisms to adapt to the depth of material things together and cross-domain collaboration.

III. PERVASIVE COMPUTING SERVICES

The service of ubiquitous computing in the Internet Thing environments is dynamic and can adapt very well distributed, heterogeneous and dynamic nature. Traditional distributed network, focusing on the distributed LAN, WAN, a computer in the network is just a node for store and deliver information. In Internet Things WAN, the positions of demand body is located accurately and move the code and the state of ubiquitous

computing services to service space [5, 6], as a result, the resources is obtained using accurate physical access control mechanisms. With the coming of next Internet Things, network bandwidth is growing, and the connections among all the things are established. The developments of communication not only means exchanging of information but also transfer the service, and the system frame and control system of Internet of Thing in the ubiquitous computations.

A. Pervasive Computing Framework for the Internet of Things

Existing WAN router as the internet main node perform to deliver data, but, in pervasive computing condition, DCS related to computing task of users will be moved in information space according to displacement in physical space to complete situational awareness and the integration of information space and physical, so the information space, a carrier need to have appropriate storage and migration of active and intelligent data mining for user location, behavior and state of DCS.

With the study of things in the technical aspects of pervasive computing service migration, this paper presents the framework of things and the level model of pervasive computing model. In this model, the storage mechanism of internet of things WAN and "Storage Service" of Pervasive Computing are employed, and revise the traditional network of "storage - forward" processing mode as the "memory - calculation - forward" model [7], to complete the task of storage, migration and the implementation for DCS. As is shown in Figure.1, the number of intelligent computing devices together constitutes the "computing area network"[7], a large-scale interoperable intelligent network is construct-ed by computing integration of vast amounts of information in the WAN. The active storage mechanism can transfer the DCS (data, code and service). In the presented model, the internet of things is based on internet, co-operate cross-domain and single applications, and perform awareness for internet thing multi-level model. It includes supporting platform, cross-border cooperation, and perception of things.

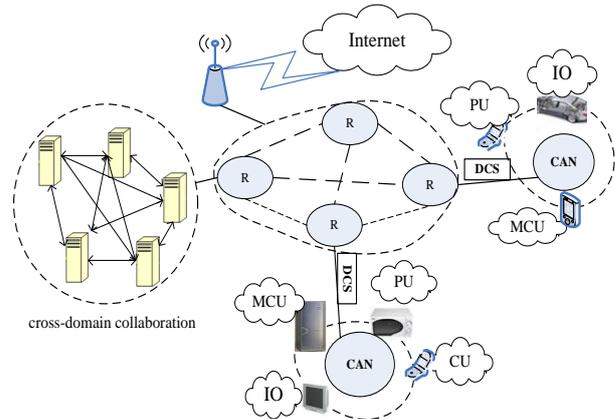


Figure 1. Framework level things ubiquitous computing

Cross-domain collaboration is an important part of internet of things, and effectively manages large-scale intelligent information resources of Internet of Things, such as, automatic correlation, DCS migration implementation. It has strong implementation ability of intelligent interactive, which is the depth of the material manifestation of joint inter-regional collaboration; to collect and DCS after analysis is complete the user to make appropriate service computing, storage and migration policy; and things associated perceived as the front end of things, to detect, identify, locate, track and monitor.

B. CAN-CSM computing area network system model

As is shown in Fig.1, the pervasive computing framework of internet of things can be divided into three levels. In the ubiquitous computing environments of internet of things, DCS can cope with the needs of the body to migrate to different computing environments, which require different equipments to form an environment computing system. The body needs to complete the DCS services include computing, display, input and output, control processing functions and so on. In this paper, in aspect of DCS storage, migration and coordination of implementation, a control system model algorithm of regional network computing is proposed, called CAN-CSM (Computing Area Network-Control System Model). As the core implementation and virtual compute nodes, it make the pervasive computing architecture of internet of things have a very good flexibility and scalability, which described in Figure 2. PU means processing unit, CU for the memory cell, IO for the input output unit, MCU for the micro-control unit.

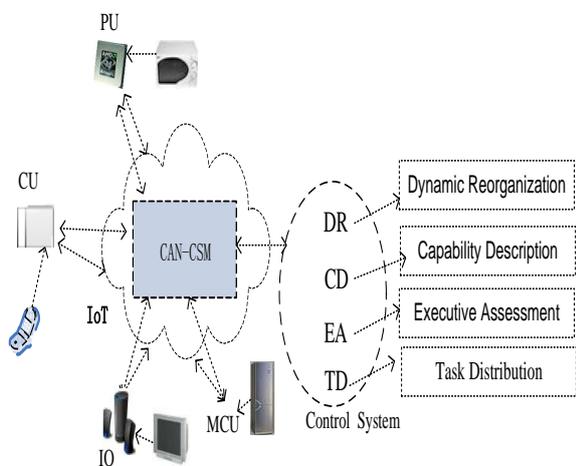


Figure 2. CAN-CSM model

In CAN-CSM model shown in Figure.2, the dynamic restructuring mechanism of virtual devices is employed to use the device with corresponding execution ability as virtual equipment components, such as I/O devices, storage devices, processor (CPU) external devices. In CAN-CSM internal virtual "system", the communication among components performed through the "bus" type of

IP data network for high-speed data transmission, and the virtual devices play the appropriate role, co-responsible for data transmission, communication, management, collaboration and other tasks, constitute the DCS mobile execution environment, as shown in Figure 3 high-speed IP data network to various parts of "connected" together.

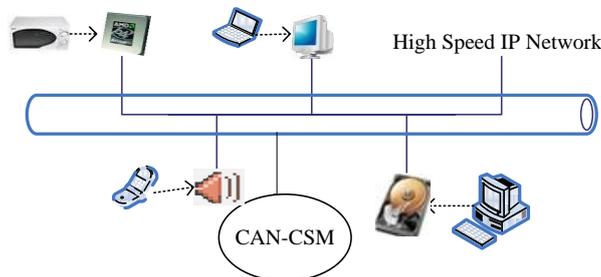


Figure 3. IP data network

With pervasive computing environment, each CAN-CSM can do with DCS code storage, migration, executing tasks, and collaborate with other CAN-CSM [15], as is shown in Figure 4. When a user enters the environment of CAN-CSM, CAN-CSM will get the information carried by the user related tasks in support of its treatment of the DCS, and the DCS will be stored in active memory systems. By using specific management mechanism to form a re-activation of equipment "virtual system", each device acts as a system role. CAN-CSM will send all the equipment code including the area code of the trust signature and the trust list of equipment and other polling information. System equipment will response code after receiving the trust information, and trust the device to dynamically modify the list of equipment and regional signature. When the device exits the system or meet malfunction, the system will dynamically delete the device information. CAN-CSM can control all devices within the system and describe, estimate equipment capabilities, distribute task to equipment with ideal ability, and the equipment included in the task list control information. System equipment can download needed DCS code in the region from CAN-CSM active storage system and other runtime environment code, performs the necessary "action." Executing code among different devices need to complete the implementation of DCS code DCS control, cloning, migration, and dispatch process.

When users shift from a CAN-CSM to other CAN-CSM, the migration of the DCS is needed firstly, and cooperation happened according to circumstances, to complete the transaction for users together.

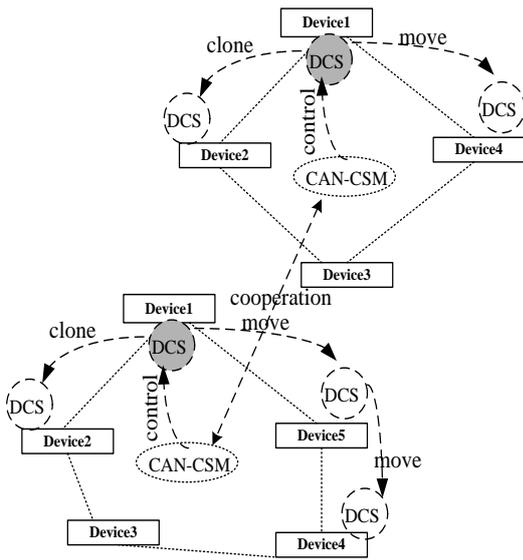


Figure 4. DCS division of labor

Internet of things is computing net which is composed of myriad of computing area network in WAN, and the control system is the core part of computation area network. CAN-CSM packages based on the perceived request generation DCS, by finding the best path routing algorithm, the DCS to the appropriate target "compute area network", the "computing area network" to access information about performing the operation. Then carrying the modified DCS continue to migrate to other "computing area network", visit all of "computing area network", the results are returned to the original source to generate its "computing area network".

IV. CAN-CSM MANAGEMENT MECHANISM

Dynamic network computing is introduced to the internet of things, the environment of internet of things is divided into a number of "computing area network" which is connected to each other, and each "computing area network" is build with a number of heterogeneous intelligent computing devices, each computing device is regard as an intelligent network node in a different "computing area network". Different computing area network has difference characteristics. How to ensure the implementation of "CAN-CSM" in application of internet of Things in the most effective manner? Its core mechanism lies in virtual device dynamic restructuring, the device capability description, evaluation and implementation of the task distribution. "dynamic reorganization for Virtual devices" refers to a variety of devices can be dynamically restructuring so as to constitute a different "computing area network" virtual computing environment, most likely to meet the implementation requirements of networking applications.

The virtual area network computing environment composed of computing area network has following characters: re-DR (Dynamic Reorganization), ability to describe the CD (Capability Description), the

implementation of assessment EA (Executive Assessment), the task distribution of TD (Task distribution), and it is also CAN-CSM management mechanism. Figure 5 shows the calculation of the regional network management mechanism.

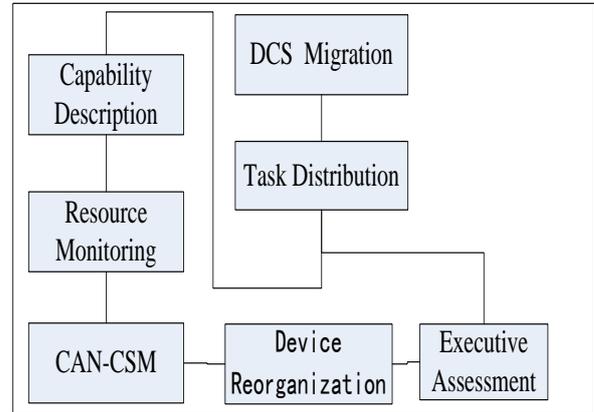


Figure 5. CAN-CSM management mechanism

A. Dynamic Reorganization

Dynamic reorganization is used in virtual computing environment of computing area network, and many intelligent computing components are reorganization into a single abstract computer. With a mechanism which are given out by CAN-CSM, all the equipments in the same computing area construct a virtual computer, and all of them can automatic fit together and cooperate with each other. When the intelligent computing devices dynamically join or leave high-speed IP network, using joining or exit mechanism of CAN-CSM, the joining request information or send out information and their information to other devices in the network [8].

Virtual device dynamic reorganization is a core manages mechanism of control system of computing area network and it allots storage space for every device. When a device need dynamically join a virtual computing environment of CAN, the following condition should be

$$R_{x_i} \cap \bigcup_{i=1}^n R_i \neq \Phi$$

met, $x_i \in \Omega$, when $N < M$ and Ω is universal set. M is the maximum area network load, the device candidate set is N , x_i is the i -th device, the device of the trust domain is R_i , a new device is added to the current virtual device candidate set, and all the equipment in computing area network is mutual trusted. when this new device add to computing area network, it will be described. The new sends join request in the computing area network with broadcast way, Within a specified time, the devices will receive the request and return a confirmation message, confirmation message is received by the new equipment and the device is set to trust set. The new device sends a confirmation to join the message, calculate the regional network device receiving the message the device will

trust a new device is set to achieve the dynamic adding equipment, as is shown in Figure 6.

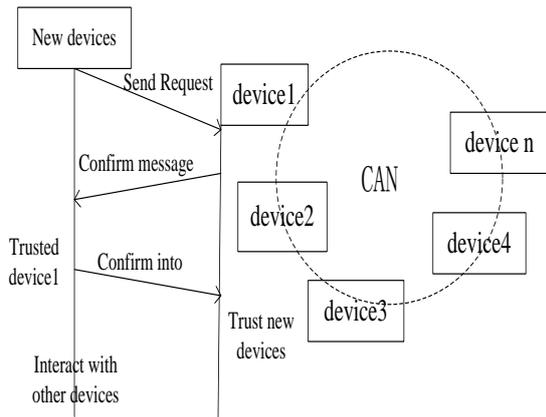


Figure 6. add device dynamically

If a device ready to quit the virtual environments, the device will firstly sent out a request in broadcast way, the remain device will respond after receipt the equipment, after received a confirmation message each other, all the devices will delete corresponding record from trust fields to implement exiting function. Fig.7 gives out the descriptions.

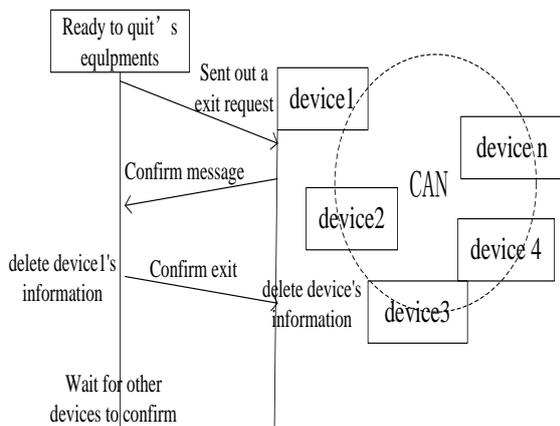


Figure 7. Device dynamic exit

In the dynamic restructuring process, for joining or leaving, if a device does not respond within specified time, the device will be regarded as abnormality, and other devices will update their trusted list. By calculating device joining and exiting for area network devices dynamically, the entering or exiting action is performed by the devices together dynamically.

Computing according to the network system and resources integration of computing area network characteristics, according to virtual layers and control methods, the control model of computing area network can be divided into several layers: application layer, services layer, storage layer, in details, it will be: storage resource layer: includes a variety of different types of physical storage resources; services layer: provides a

way to access and control interfaces; application Layer: Provides access to the service function needs the body can easily access services.

B. CD (Capability Description)[9]

After restructuring and building a good "computing area network", the various heterogeneous intelligent computing devices, "integration" of the computer, how to achieve interoperability of components and inter-communication? The key is how to unify description of the device and user needs. The capacity management mechanism is needed for CAN-CSM, and with the ability matching algorithm appropriate device are searched according to user needs.

In each CAN-CSM, a management server is needed, and the server aims to describe the device ability in CAM. Ability of the device management server has the following function: ability to collect, verify information automation, management mechanism, the unity of description, it also include the calculation of the regional network and information description of required resources. Figure 8 shows the ability of management mechanism. The ability collect adopt online mode, using the appropriate acquisition protocol to describe index information of device identification, device type, device size, input and output parameters, interface information, equipment suitable environment, equipment storage capacity, equipment capacity to handle the border and other key performance indicators. Right equipment data can just ensure the serve quality and describe the hardware, software, network even validate them and maintain devices. The equipment capacity is described in the management capacity of the device according to classified information, to provide information database storage and processing capabilities, the ability to provide equipment management, including access interface device structure, behavior, boundaries and other regulations. The ability to quickly search for equipment handling, build capacity of heterogeneous devices fast mapping, equipment or components to achieve heterogeneous interoperability between and "seamless" integration.

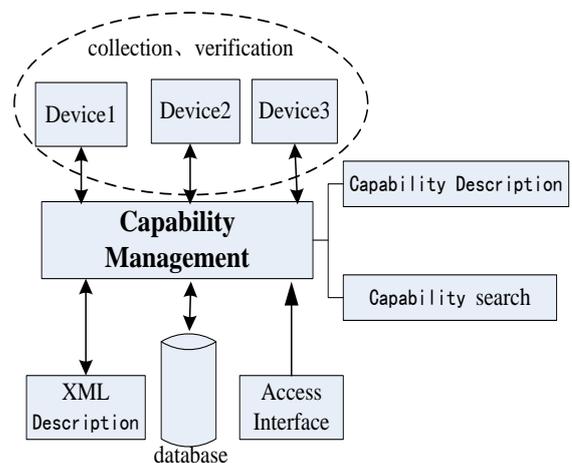


Figure 8. Capability management mechanism

XML text is always employed for ability manage servers to describe ability of devices, and figure 9 figure out the basic ability description:

```

<?xml version="1.0" encoding="utf-8"?>
<Capability
xmlns:xsi="http://www.w3.org/2001/XMLSchema-
instance">
<Basic>
  <name>...</name>
  <logo>...</logo>
  <type>...</type>
  <Storage-capacity>... </Storage-capacity>
  .....
</Basic>
<Interface>
  <input>
    <parameter>...</ parameter>
  </input>
  <output>
    <parameter>...</ parameter>
  </output>
</Interface>
<Interaction>
  .....
</ Interaction>
</ Capability>
    
```

Figure 9. Capability Description Example

In the CAN control system, unified management system is used for manage parameters of each node in the network equipment and CD and re-calculate the ability description for regional network device capabilities description after regrouped devices dynamically. As new devices join or leave the computing network, ability manage servers of CAN use ability search algorithms to find components or equipment. According to the role of current equipment in the local environment, and combining with the CD mechanism in the allocation of new equipment "system" function to adjust the role of a virtual computing environment or "system" components

C. EA (Executive Assessment)

Context in pervasive is defined in internet of things, and it is used to express spatial information, environmental information, accessible resources. Accessible resources can be used to assess the efficiency of DCS code. Reference result has linearly proportional relationship to resources number[10,11], If D is the implementation of results, and the R is the amount of resources, in certain time t, D is expressed as the implementation of the results:

$$D(t) = KR(t) \tag{1}$$

Where, K is relationship coefficient, when the amount of resources changes, the number of resources available and the implementation of decisions will change accordingly.

Considering the hardware implementation loss and a virtual IP network loss and other factors, downgrade

approach for implementation of assessment can be used to complete the assessment implementation efficiency and effect.

let di is device number in a computational area network, which i = 1,2,3 ... m. Devices cooperate to finish migration and computing task. Rj computing resources for the tasks to be processed resources, such as DCS or computing operations, which j = 1,2,3 ... n.

After CAN-CSM receives the DCS and related resources, it execute tasks, call the implementation of ATLAS resources Di implementation capacity of the equipment to evaluation system to value device resource Di and feedback the results of the implementation of $(r_j, d_i) \subseteq D_{ji}$, which i = 1,2,3 ... M, j = 1,2,3 ... n, Dji is for different devices with the ability to execute a task resource set. Evaluation system deliver the best result for each computing resource rj in computing area network and mapping information of equipment resources of di so as to facilitate the task scheduling for this time and estimation reference for next implementation.

D. TD (Task distribution)

In computing area network there may many DCS migration and computing tasks simultaneously or queued for execution in the same time, how to make ubiquitous computing environment of internet of things reasonable and balance distribution of tasks to computing area networks, and to load heavy task devices or malfunction devices to light load equipment in real-time, so as to balance the system load and improve the overall system capacity and quality of service? [12]. Ability adjustment of spare dispose of device is finished by redundancy feedback of load capacity.

V. CAN-CSM SECURITY

CAN-CSM is designed for an open network environment, and the security face a variety of factors. CAN-CSM use mobile networks to finish migration for DCS data, code and state of service, so the CAN-CSM safety is closely related to security of DCS services migration, mainly reflected in:

- (1) security of communication, transmission and collaborative among "CAN-CSM", and no uninterrupted communication happen among CAN.
- (2) during the migration process DCS will not be tampered and it is not illegal CAN-CSM control and treatment.
- (3) DCS will not protect the non-purpose servers on their own run server; privacy of DCS user is not compromised.

In ubiquitous computing environment of internet of things, mobile scene is one of its characteristics, and its related computing and business applications rely mainly on the computational domain as the main decision making of the reference variable. Fully Homomorphic Encryption (full homomorphism encryption)[13] can be used to improve its security. Ensure the security of communications between the DCS; using identification

form validation code in DCS to complete carrying authentication and access control, when trust domain migrate DCS, CAN-SCM will compare the trust domain, and gives prompt. it will refuse DCS migration and communication services for unsafe communication DCS.

VI. FUTURE WORK

(1) in ubiquitous computing in the Internet of Things, DCS service migration is a very important job, for the use of local area network consisting of several computers, it is a relatively simple task. DCS migration change according to requirements in different "computing area", among the heterogeneous, distributed and dynamic software platform and hardware environment in real time, and the best path of DCS migration should be an important research work.

(2) in the "computing area network", the body related automatic relationship and control of implementation of intelligent collaboration are all related to cross-domain collaboration. Resource integration, intelligent interaction, the general adaptation highly integrated system support, and it is the next stage important research work.

(3) the operational reliability and scalability of pervasive computing environment depends on the application architecture[15]. how to construct the things pervasive computing application framework based on the "calculated area network", and fully embodies the things of ubiquitous computing distributed, heterogeneous and dynamic nature, which is also next research work contents.

VII. CONCLUSION

CAN-CSM based on ubiquitous computing of internet of things which is composite of numerous virtual composition areas. With CAN-CSM devices are dynamically recombined as computing component by virtual devices recombination technology, and a number of devices to form a virtual computing "system". Lots of technologies are used, such as description of equipment capacity, the ability search, execution and implementation of effective assessment, task distribution, to implement users DCS migration, services, calculation, reflecting the general proper calculation of "computing to adapt human" characteristics in environment for ubiquitous computing of internet things.

In addition, the paper also discuss CAN-CSM security issues and future work. Pervasive computing of internet of things is a new cross-research, and it will bring innovation to internet services and it will play a more important role in the next generation of computing technology and in the production and life of human. In the same time, it bringing new challenges and opportunities

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REFERENCES

- [1] Weiser, M. The Computer for the Twenty- First Century [J]. Scientific American, 1991(3):94-100.
- [2] EPCglobal, the EPCglobal Network: Overview of Design, Benefits, & Security, 2004.
- [3] Yu Ying-qun, Cai Xiao-dong On the instability of slotted ALOHA with capture [J]. IEEE Trans on Wireless Communications, 2006, 5(2): 257-261.
- [4] Zhang Yunyong, Liu Jinde. Mobile agent technology [M]. Beijing: Tsinghua University Press, 2003: 20-34 [11].
- [5] Dejan Molojic. Mobile Agent application from Trend Wars. IEEE concurrency.
- [6] Huang hai-ping, Wang ru_chuan, Sun li-juan, Jiang hao. Pervasive Computing science Apperceive Model Based on Agent & Wireless Sensor Networks [J]. Journal of Nanjing University of Posts and Telecommunications. 2008. vol. 28 No. 2.
- [7] TENNENHOUSE D L, SMITH J M, SINCKIE W D, et al. A survey of active network research [J]. IEEE Communication Magazine, 1997, 35(1): 80-85.
- [8] Lu Jun, Lu Xianliang, Han Hong, Wei Qingsong. ACAWM: High Performance Write Cache Management Mechanism for NAS [J]. computer science 2002 vol. 29 No. 12.
- [9] Zhao Long-en, Hou yi-bin. capability description for cooperation Agents [J]. MINI-MICRO system. 2003 vol. 24 No. 2.
- [10] Li Yun, Luo Lei, Xiong Guang-ze. The Adaptive technology for pervasive computing [J]. Acta electronica sinica. 2004 vol. 32 No. 5.
- [11] Guo Benjun, Lu Jun, Yue Xi, Huang Jian. "A New Virtual Computing Model of Area Network" [J]. 2010 International Conference on Future Computer, control and Communication (IEEE). Vol. 2. 13-16.
- [12] Gong Mei, Wang Peng, Wu Yue. Transparency dynamic feed-back load balancing algorithm based on cluster system [J]. Computer Applications. Nov. 2007 Vol. 27 No. 11.
- [13] C. Gentry. Fully homomorphic encryption using ideal lattices. In Proc. of STOC, pages 169-178. ACM, 2009.
- [14] Lu Jun, Lu Xianliang, Han Hong, Xu Teng. The Research of Mobile Agent-based Distributed File System [J]. Computer Science. 2002, 29(10).
- [15] Shen Zhan-feng, Luo Jian-cheng, Cai Shao-hua, zheng Jian, chen Qiu-xiao, Sun Qing-hui. Architecture of Grid-GIS and Its Key Techniques [J]. Geo-Information Science. 2003 5(4).



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