An Effective Cooperation Mechanism among Multi-Devices in Ubiquitous Network

Shaoyong Guo, Lanlan Rui, Xuesong Qiu, Luoming Meng
State Key Laboratory of Networking and Switching Technology
Beijing University of Posts and Telecommunications, Beijing, China
E-mail: syguo@bupt.edu.cn

***Abstract*—The aim of MANET is to supply ubiquitous services through communications among a set of devices deployed in ubiquitous stub environment. Due to the dynamic characteristics of MANET and the limit of devices' capacity, it is a critical challenge to select an optimal set of device to supply high quality service constantly. In this paper, the Multi-Devices Cooperation problem is imported with ubiquitous service model and network model. And a dynamic multi-devices cooperation approach is proposed to support three processes of service requiring, multi-devices cooperation selecting and quality maintenance. At last, the simulation is implemented with OPNET and MATLAB and the result shows this approach is better applied to support ubiquitous services.**

Keywords- Ubiquitous Service; Multi-Devices Cooperation problem; dynamic multi-devices cooperation approach

I. INTRODUCTION

The vision of pervasive computing is to create a smart space (e.g. a home, office, or campus) called a ubiquitous stub environment where users can enjoy ubiquitous service in an "anytime, anywhere, on any device" manner. In ubiquitous stub environment, a ubiquitous service is regard as a distributed application and consists of a set of less complex and smaller services that are deploying on multi-devices to improve service's quality, especially in MANETs. It is the reason and target to supply ABE (Always Best Experience[1]) for users in process of service execution in MANETs. However, due to the dynamic characteristics [2] of MANET and the limit of device capacity, it is a critical challenge to select an optimal set of device to supply high reliable service constantly. Thus, building an effective cooperation mechanism among multi-devices is major problem in ubiquitous network.

As a critical problem to service automation in ubiquitous stub environment, it received significant attention at present from researchers. Zhang [3] proposed MUSE (Mobile Ubiquitous Service Environment), with TSE (Terminal Service Environment) and ABE, constructing future prospect through multi-devices cooperate to support distributed services in ubiquitous network. IEEE802.15.3 [4] integrates many network factors (such as transmitter power, PHY rate, and MAC address) into constructing piconets to support high quality of services. And Gopalan [5] introduced SARA (Service Architecture for Resource Aware) to build a mechanism to guarantee seamless service delivery based devices' context. But it is ineffective to safeguard quality of services and inapplicability to diversity service requirements. In additional, two typical methods are DTA [6] and SDA [7]. DTA is dynamic task alliance with a tree-based services model. And SDA is to extend the limit of DTA for diversity services with Graph-based service model. However, it is hard to aware the reducing of local service quality so that it can't support the global high quality service requirement. Thus, this paper would provide an effective multi-devices cooperation mechanism based on DTA and SDA to apply in ubiquitous network.

To address this open issue, the paper generalizes and formulates a MDCP (Multi-Devices Cooperation Problem) to quantitatively characterize and measure the utility of ubiquitous service. And the objective of MDCP is to select exactly DCS (Device Cooperation Set) for requested ubiquitous service such that the utility is maximized. Secondly, a dynamic multi-devices cooperation mechanism is proposed to deal with MDCP in which there are three processes in ubiquitous service executing cycle: service requiring, device selection and service maintenance. At last, the simulation is implemented with OPNET and MATLAB. And the results are analyzed in detailed with Energy Consumption, Packet Loss Ratio and Re-start Time to show that it performs better than DTA and SDA.

II. SERVICE-ORIENTED MULTI-DEVICES COOPERATION PROBLEM

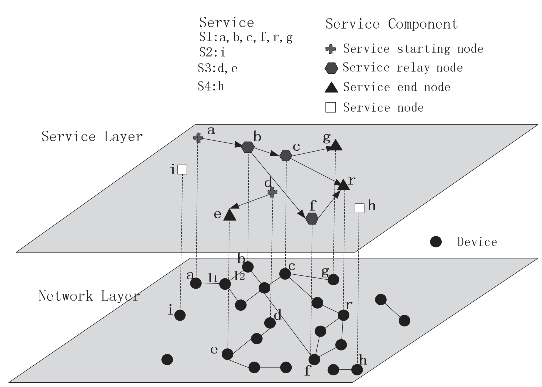

Fig.1 Service-oriented Multi-Devices Cooperation Environment

As shown in Fig.1, there have two layers: service layer and network layer. The aim of MDCP is to find optimal DCS in network layer for ubiquitous service in service layer. For example, service $S1$ in Fig.1 is consisting of six sub-services $\{a, b, c, f, r, g\}$ in service layer and those sub-services

978-3-901882-48-7 ©2012 IFIP

are executed on different devices in network layer. Our goal is to provide stability ubiquitous service that enable highly reliable service delivery and provide the best utility for users. To focus the discussion on impact of service quality, this paper imports QoS-metric with Multi-attribute Decision Making as utility function. Additionally, device capacity and bandwidth on network are viewed as constraint conditions in MDCP. USM(Ubiquitous Service Model) and NM(Network Model) are defined to model ubiquitous service and networks.

A. Ubiquitous Service Model

USM is defined as the structure of a ubiquitous service. For ubiquitous service i (i=1...I), it consists of two sets about the sub-services set $S_i=\{s_{i,h}|h=1,...,H_i\}$ and the interaction set $L_i=\{l_{i,u}|u=1,...,U_i\}$. $s_{i,v}$ is v–th sub-service in ubiquitous service i . And $l_{i,u}$ is one interaction of the requested ubiquitous service i. The ubiquitous service i is represented by an undirected graph $G_{USM}(S_i,L_i)$ as shown in Fig.1 in which S_i and L_i are vertex set and edge set, respectively.

B. Network Model

NM is the network structure in ubiquitous stub environment. We consider network as $G_{UN}(D,E)$ in Fig.1, consisting of a set of devices $D=\{d_k|d_k,k=1,...,K\}$ and the network connectivity set $E=\{E_e|E_e,e=1,...,O\}$. $R_k=\{R_{k,w}|R_{k,w},k=1...A,w=1...W\}$ is imported to indicate the available value of capacity type k on device $d_k \in D$ and the available bandwidth on network connectivity $E_e \in E$. $G_{UN}(D,E)$ is a undirected graph model and change with mobility and capacity limit of each device in this network.

C. Math Model

The problem of MDCP is how to dynamically select device set to execute the ubiquitous service $G_{USM}(S_i,L_i)$ from $G_{NM}(D,E)$. The ubiquitous service should satisfy certain QoS to improve users' experience. However, the QoS indexes are diversity and it is hard to set the weight value if these are to through setting different weight value for each QoS index and computing with linear function[5]. Therefore, this paper use Multi-attribute Decision Making to dimensionless processing QoS-metric and defined dimensionless utility function with QoS indexes as the objective function of MDCP to reflect users' utility. During the process of multi-device cooperation, there would have many solution in DCS, defined as $C_m(m=1,...,M)$, to be selected to execute ubiquitous service. We cite $P_i=[p_{mn}]_{M\times N}$ as cooperation result matrix to weigh the utility of each solution for ubiquitous service i . And p_{mn} is parameter value of utility index $I_n(n=1,...,N)$ in C_j . In order to compare different index, we need to design a theoretical method to dimensionless processing. After dimensionless processing, we get $P_i^{'}=[p_{mn}^{'}]_{M\times N}$ from $P_i=[p_{mn}]_{M\times N}$. The computation of $P_i^{'}=[p_{mn}^{'}]_{M\times N}$ is computed with the character of index computation and these indexes are classified as following:

1) **Efficiency index:** it refers that the result will be increased by improve the index value defined as Formula 1, such as bandwidth availability, surplus energy and memory.

$$p_{mn}^{'}=\begin{cases}\dfrac{p_{mn}-p_n^-}{p_n^+-p_n^-}, & p_n^+-p_n^-\neq 0\\ 1, & p_n^+-p_n^-=0\end{cases} \tag{1}$$

Here, $p_n^+=\max\{p_{mn}|m=1,...,M\}$ and $p_n^-=\max\{p_{mn}|m=1,...,M\}$.

2) **Cost index:** it refers the result will be increased by dropping the index value, such as communication cost and energy loss. And those indexes' computation is defined as Formula 2.

$$p_{mn}^{'}=\begin{cases}\dfrac{p_n^+-p_{mn}}{p_n^+-p_n^-}, & p_n^+-p_n^-\neq 0\\ 1, & p_n^+-p_n^-=0\end{cases} \tag{2}$$

Here, $p_n^+=\max\{p_{mn}|m=1,...,M\}$ and $p_n^-=\max\{p_{mn}|m=1,...,M\}$.

After get $P_i^{'}=[p_{mn}^{'}]_{M\times N}$, this paper introduces TOPSIS [10] to compute the utility of service i . The basic idea is to get ideal solutions $V^+=\left(v_1^+,...,v_n^+\right)$ in Formula 3 and minus ideal solution $V^-=\left(v_1^-,...,v_n^-\right)$ in Formula 4 to construct dimensionless $V=[v_{mn}]_{M\times N}$, then calculate the comprehensive utility value φ_i for the solution as shown in Formula 5.

$$v_n^+ = \max\left\{v_{mn}|m=1,...,M\right\} = \omega_n \times \max\left\{p_{mn}^{'}|m=1,...,M\right\} = \omega_n \times p_{mn}^+ \tag{3}$$

$$v_n^+ = \max\left\{v_{mn}|m=1,...,M\right\} = \omega_n \times \min\left\{p_{mn}^{'}|m=1,...,M\right\} = \omega_n \times p_{mn}^- \tag{4}$$

$$\varphi_i = \max_{m=1,...,M}\left\{\frac{y_m^-}{y_m^+ + y_m^-}\right\} \tag{5}$$

$$\text{s.t.}\ \begin{cases} y_m^- = \sum_{n=1}^{N}\left\|v_{mn}-v_n^-\right\| = \sum_{n=1}^{N}\omega_n^2\left(p_{mn}^{'}-p_n^{'-}\right)^2\\ y_m^+ = \sum_{n=1}^{N}\left\|v_{mn}-v_n^+\right\| = \sum_{n=1}^{N}\omega_n^2\left(p_{mn}^{'}-p_n^{'+}\right)^2\end{cases}$$

Additionally, ω_n is defined as Formula 6.

$$\omega_n=\frac{1}{\sum_{n=1}^{N}\frac{1}{\sum_{m=1}^{M}\left(p_{mn}^{'}-p_{mn}^{'+}\right)^2}\sum_{m=1}^{M}\left(p_{mn}^{'}-p_{mn}^{'+}\right)^2} \tag{6}$$

In this paper, φ_i is viewed as the objective function and the model of MDCP is defined as shown in Formula 7 with constrain conditions of device capacity and bandwidth.

$$max\ \sum_i F(i,P_i)=\sum_i \varphi_i \tag{7}$$

$$s.t.\ \begin{cases}\sum_{i=1}^{I}\sum_{m=1}^{P_i}\sum_{h=1}^{H_i} r_{h,w}^i\cdot x_{m,h,k}^i \le R_{k,w}, & \forall w,k\\ \sum_{i=1}^{I}\sum_{m=1}^{P_i}\sum_{u=1}^{U_i} b_u^i\cdot y_{m,e}^i \le E_e, & \forall e\end{cases}$$

Here, P_i is DCS for executing ubiquitous service i ; $x_{m,h,k}^i$ and $y_{m,e}^i$ are 0-1 variable defined as Formula 8 and Formula 9.

$$x_{m,h,k}^{i} = \begin{cases} 1, & \text{if } d_k \text{ is select to carry out} \\ & \text{ubiquitous service } i \text{ in } P_i \\ 0, & \text{otherwise} \end{cases} \quad (8)$$

$$y_{m,e}^{i} = \begin{cases} 1, & \text{if } E_e \text{ is selected to carry out} \\ & \text{ubiquitous service } i \text{ in } P_i; \\ 0, & \text{otherwise} \end{cases} \quad (9)$$

III. Dynamic Multi-Devices Cooperation Approach

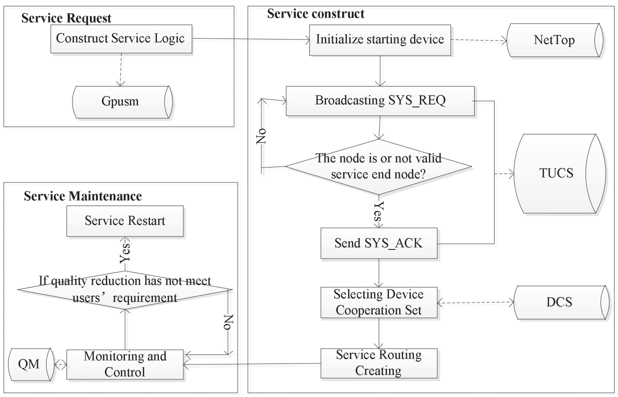

Fig.2 dynamic multi-devices cooperation Approach

In ubiquitous stub environment, *a dynamic multi-devices cooperation approach (MDCA)* is proposed to deal with MDCP in which there are three processes in ubiquitous service executing cycle: service requiring, device selection and service maintenance. The main processes are shown in Fig.2, consisting of three main parts: service request, service construct and service maintenance. During the stage of service request, Service Logic Model is constructed to support device selection and presents USM. And then it uses BFS (Breadth First Search) and pruning strategy based on DTA and SDA to design dynamic MDCA in service construct stage. At last, service maintenance module is to monitor and restart the ubiquitous service when service quality decline.

A. Service Request

In dynamic MDCA, a requested ubiquitous service is represented by a service logic model $G_{USM}(S,L)$ on the service starting device. Besides, local network topology $NetTop=\{DE, Gbit\}$ is also initialized on this device. $DE = \left(d_{k_0}, d_{k_1}, ..., d_{k_h}, ..., d_{k_H}\right)$, d_{k_h} is the device to executing $h-th$ sub service for $G_{USM}(S,L)$ and $Gbit$ is mark bit which represents the sub service whether execute on one device. The initialization of DE is $DE=(NULL, NULL, ..., NULL)$ and $Gbit = 00...0$. For an example, as shown in Fig.3, the $G_{USM}(S,L)$ of ubiquitous service S1(In Fig.1) has $\{s_0, s_1, s_2, s_3, s_4, s_5\}$ for $\{a,b,c,f,r,g\}$ in Fig.3 which is represented as Formula 11.

$$G_{USM}(S,L) = \begin{bmatrix} 0\,1\,0\,0\,0\,0 \\ 1\,0\,1\;1\,0\,0 \\ 0\,1\,0\,0\,1\;1 \\ 0\,1\,0\,0\,1\,0 \\ 0\,0\,1\,1\,0\,0 \\ 0\,0\,1\,0\,0\,0 \end{bmatrix} \quad (11)$$

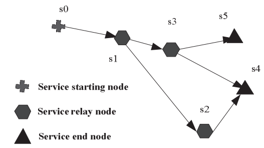

Fig.3 Service Logic Model of S1

Here, if $g_{kh} = 0, \forall k < h$, then device h is service starting node which would broadcast SYS_REQ to get network context; if $g_{kh}=0, \forall k>h$, device h is service end node which will send SYS_ACK to service starting node with network context record for service delivery; and other nodes are service relay nodes which support service traffic and data traffic.

B. Service Construct

The main process of service construct is to broadcast SYS_REQ with TTL by service starting node and receive SYS_ACK from service end node to construct $G_{USM}(S,L)$ and $NetTop=\{DE, Gbit\}$ for selecting device cooperation set on service starting device as show in Fig.4. The main processes of MDCA are as following: Firstly, one device would construct $G_{USM}(S,L)$ and initialize $NetTop=\{DE, Gbit\}$ when received a requested ubiquitous service, and then broadcast SYS_REQ with TTL=T. Secondly, other devices received SYS_REQ would judge their role in service execute. If the device is only to support service relay node, then then it appends its context information into SYS_REQ and broadcasts it with TTL=T to other devices until find service end node. Thirdly, if the device is valid to support service end node, then it would append its context information into SYS_REQ, transfer SYS_REQ to SYS_ACK and send SYS_ACK to service starting node with $TUCS$. At last, the service starting node has received all SYS_ACK in a time and forms UCS (As shown in Formula 12). And then select DCS with MDCP model and send INS_ACK to all devices in DCS for establish service routing.

$$UCS=\begin{Bmatrix} DE_1, & \rho_{1,1}, \rho_{1,2}, ..., \rho_{1,N} \\ DE_2, & \rho_{2,1}, \rho_{2,2}, ..., \rho_{2,N} \\ ......, & ...... \\ DE_m, & \rho_{m,1}, \rho_{m,2}, ..., \rho_{m,N} \end{Bmatrix} \quad (12)$$

Here, $\rho_{m,n}$ represents value of $n\text{–}th$ index in DE_m .

C. Service Maintenance

Service maintenance module is responsible to monitor and maintain the executing process of ubiquitous service. The mobility and the failure of devices cause service quality decline in ad hoc network so that it is unavailable to support high quality service. At time, service maintenance module would restart service and re-select DCS for requested ubiquitous service. QM (Quality Maintenance) is used to record the last utility values in an acquisition cycle. For requested ubiquitous service i , QM is defined as $QM_i=(\rho_{i1}, \rho_{i2}, ..., \rho_{iN}, \varphi_i)$. If $\varphi_i \le \varphi_{i,0}$ ($\varphi_{i,0}$ is the lowest utility value for requested ubiquitous service i), then restart service and re-select DCS that enable highly reliable ubiquitous service.

IV. SIMULATION ANALYSIS

A. Simulation Environment

Service Distance, Availability and Reliability are used to reflect user experience, terminal ability and network state. Simulation parameters are shown in table 3.

1) **Service Distance:** It is to show the difference between the average distance from a user to the device and the best distance for a user to use a specific service performed on those devices as shown in Formula 13.

$$\rho_{i,dis}=\frac{d(d^i,\mu,\sigma)}{d(\mu,\mu,\sigma)} \qquad (13)$$

Here, $d^i=\frac{\sum_{v=1}^{v_i}\left\|d_v^i-d_0^i\right\|}{v_i}$, d_0^i is requiring location of service i, and $d(d,\mu,\sigma)=\frac{1}{\sigma\sqrt{2\pi}}\exp(-\frac{(d-\mu)^2}{2\sigma^2})$, μ is the expecting distance from user to devices, σ is sensitivity to service distance.

2) Availability: the time interval between when a user requests a service on those devices and when the user receives the response which is defined as Formula 14.

$$\rho_{i,del}=\begin{cases}1-\frac{T_i}{T_{max}}, & T_i \le T_{max}\\ 0, & T_i > T_{max}\end{cases} \qquad (14)$$

T_i is response time; T_{max} is the device regarded as successfully responded if $T_i \le T_{max}$.

3) Reliability: the probability that service i performed normally on those devices which is defined as Formula 15.

$$\rho_{i,rel}=\omega_1 \cdot Cap+\omega_2 \cdot mobil \qquad (15)$$

Here, Cap is service capacity; $mobil$ is mobility of device;

Table 3 Simulation parameters

Parameter Name	Value
Number of users	1, 4, 8
Total User Number	60+ number of users
Maximus workload	5 users
Simulation area	100*100（m^2）
Initial energy	1000（J）
Routing protocol	AODV
Transmission radius	30(m)
Mobility model	Random waypoint model
Maximum speed	1,5,10,15,20 (m/s)
Mac protocol	IEEE 802.11
Simulation time	250(s)

B. Result Analysis

To compare the performance of the MDCA, SDA and DTA approaches, the simulation results are described as follows:

1) **Energy consumption:** We observed the accumulated energy consumed by all selected devices. As shown in Fig.4, MDCA approach saves 0-22% than SDA and saves 0—43% than DTA in energy consumption. The advantage of MDCA approach is more applied to multi-users' environment.

2) **Packet Loss Ratio:** we measured the packet loss ratio. As shown in Fig.5, it is reasonable that the packet loss ratio in MDCA approach is lower than that in the DTA and SDA, especially in the scenarios with four users in Fig.9b. And it saves about 5%—20%.

3) **Re-start Time:** At last, the Re-start Time is examined to reflect the service continuity. The number of service interruptions is effectively reduced in MDCA as shown in Fig.6a. Fig.6b shows that the MDCA is short than that in the SDA and DTA about the time spent on initialization in. And Fig.6c thus shows that the MDCA still performs well with regard to the re-start time.

V. CONCLUSION

This paper proposes a dynamic multi-device cooperation approach to solve the MDCP. However, the present research focuses on solving an optimal set of devices for each requested ubiquitous service. Thus, our next stage work is to design a global multi-devices cooperation mechanism in multi-user and multi-service ubiquitous environments.

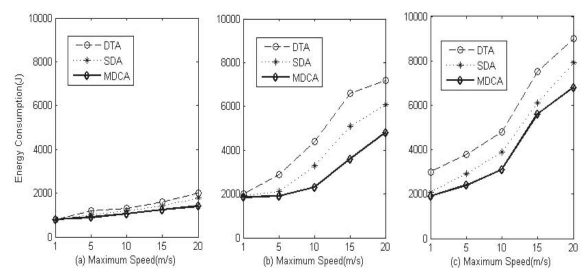

Fig.4 Energy Consumption at various maximum speeds with (a) 1 user, (b) 4 users and (c) 8 users

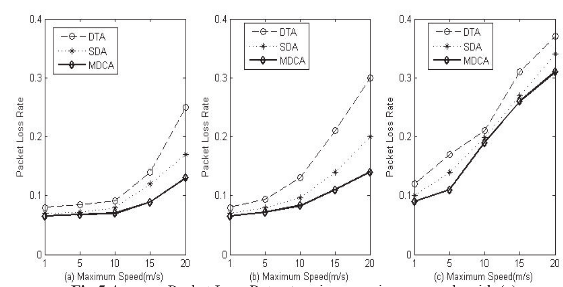

Fig.5 Average Packet Loss Rate at various maximum speeds with (a) 1 user, (b) 4 users and (c) 8 users

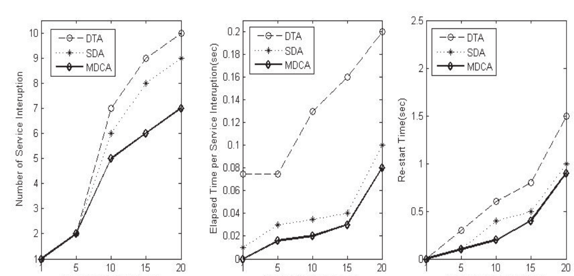

Fig. 6 (a) Number of service interruption, (b) average time elapsed per re-selecting process, and (c) average re-start time at various maximum speeds with 8 users

ACKNOWLEDGMENTS.

The work was partially Supported by 863 Program (2011AA01A102), the National S&T Major Projects (2011ZX03005-004-02), the Funds for Creative Research Groups of China (61121061), and National Key Technology R&D Program (2012BAH06B02)

REFERENCE

[1]. Zhang Ping, Miao Jie, Hu Zheng, TIAN Hui, A Survey of Ubiquitous Network, Journal of Beijing University of Posts and Telecommunications, Vol.05, 2010, Pages: 1-6[J].

[2]. Jianping Wang, Exploiting Mobility Prediction for Dependable Service Composition in Wireless Mobile Ad Hoc Networks, IEEE Transactions on Services Computing , Vol. 4(1), 2011, Pages: 44-55[J].

[3]. Ji Yang, Ping Zhang, Hu Zheng, Towards Mobile Ubiquitous Service Environment, Springer Wireless Personal Communications, Vol.38(1), 2006, Pages:67-78[J].

[4]. R.F. Heile et al, IEEE Standard Part 15.3: Wireless Media Access Control (MAC) and Physical Layer (PHY) Specifications for High Rate Wireless Personal Area Networks (WPANs), IEEE, 2003.

[5]. Anandha Gopalan, Taieb Znati, SARA: A service architecture for resource aware ubiquitous environments, Pervasive and Mobile Computing, Vol.6(1), 2010, Pages: 1-20[J].

[6]. P. Basu, W. Ke, T.D.C. Little, Dynamic task-based anycasting in mobile ad hoc networks, Mobile Networks and Applications, Vol.8(5), 2003, Pages: 593–612[J].

[7]. Wei-Tsung Su, Yau-Hwang Kuo, Po-Cheng Huang, A QoS-driven approach for service-oriented device anycasting in ubiquitous environments, Computer Networks, Vol.52(18), 2008, Pages: 3342-3357[J].

[8]. Zhongliang Yue, Extension of TOPSIS to determine weight of decision maker for group decision making problems with uncertain information, Expert Systems with Applications, Vol.39(7) , 2012, Pages: 6343-6350[J].