Middleware Services with Context Aware Intelligent Decisions for Disconnection Tolerant Mobile Applications

Sangwhan Cha and Weichang Du

***Abstract*—In order to effectively maintain mobile application services in spite of sudden network disruption, middleware services with context aware intelligent decisions are required on the mobile device and the Mobile Intelligent Server (MIS) located between mobile devices and servers. Middleware services provide the management of mobile services, network connection, limited resource and context information. In this paper, we propose middleware services with context aware intelligent decisions for disconnection tolerant mobile application services. Such middleware services manage runtime application and networking contexts for intelligent decision making of the middleware.**

***Index Terms*—Middleware, context awareness; intelligent decision; mobile application.**

I. Introduction

The ultimate goal of mobility in wireless computing for the next generation network is the seamless service mobility [1-3], which is defined as the ability of a mobile user to access the particular subscribed services anytime and anywhere seamlessly with various mobile devices, while he is moving from one access network to another access network. In addition to the seamless service mobility matter, there is another important consideration for mobile application services in case of network disruption.

As long as there are two kinds of network disconnections such as gradual network disconnection and sudden network disconnection, we need several decisions required for both kinds of network disconnections on the starting point to prepare for network connection loss. The first decision required is related to the question how we are able to know that a device is getting out of coverage area and going to be disconnected for gradual network disconnection. The second decision required is related to the question how we are able to know when the device should start to make preparation for gradual network disconnection. The third decision required is related to the question how we are able to know that a device is getting out of coverage area and going to be disconnected for sudden network disconnection. The fourth decision required is related to the question how we are able to know when the device should start to make preparation for sudden network disconnection.

With the proposed middleware services [4], [5], proper context aware intelligent decisions are needed to provide effective mobile application services in spite of sudden network disruption.

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The authors are with University of New Brunswick, Canada (e-mail: scha@unb.ca).

In this paper, we propose middleware services with context aware intelligent decisions that transparently perform required functionality to users.

The rest of this paper is structured as follows. Section II discusses previous work. Section III introduces context aware intelligent decisions and Section IV describes our experiment and evaluation based on previous work. Finally, Section V gives some concluding remarks.

II. System Overview

In the previous work [4], [5], Fig. 1 illustrates the general model for MIS-based architecture. MIS is located in the fixed network and has reliable connections to the application server. When the disruption in the wireless access network occurs, the middleware on the mobile device will try to make the mobile application run as long as possible with limited resources until reconnection, and the MIS still manages data from the application server for future update to the mobile device when the network is reconnected between the mobile device and the MIS.

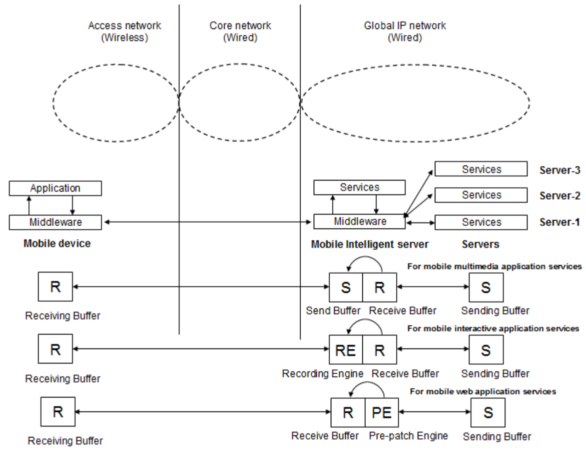

Fig. 1. A general model for the middleware solution.

For mobile multimedia application (ex. video) services, the MIS sets higher sending rate when the decision making on the network disruption is made based on context information so that the mobile device may reserve more data before network disruption.

For mobile interactive application (ex. game) services, the MIS makes mobile interactive services be recorded using recording engine during disconnection period and updated in the mobile device after reconnection.

For mobile interactive application (ex. web) services, the MIS makes the first level web pages be pre-patched using pre-patch engine when the decision making on the network disrupt is made based on context information in order to make mobile device be run able during disconnection period.

III. Context Aware Decisions

In order to make proper preparation for gradual network disconnection, we need two context aware decisions. With regard to the first context aware decision, we have to decide whether a device is getting out of coverage area and is going to be disconnected. We apply incremental method with signal strength. The decision only with signal strength is called direct decision. Table I shows context information for direct decision making.

TABLE I: Context Information for Direct Decision Making

Context	Dimension	Range	Abbreviation
Network	Signal strength	1~10	N_SS

The process of direct decision making is following.

If $N\_SS_i - N\_SS_{i-1} > 0$, let $K_i = 1$, where N_SS_i is network signal strength at time i.
else if $N\_SS_i - N\_SS_{i-1} < 0$, let $K_i = -1$
else $K_i = 0$.

For setting the starting point for decision making, let $inc(N\_SS_{t-n})$ be the sum of K_i for some period time (t-n) from the start time (n) of mobile application to current time (t). Then, the process of decision making starts when N_SS_t is less than and equal to handoff threshold and $inc(N\_SS_{t-n})$ is less than zero, where N_SS_t is network signal strength at the current time t.

For the process of decision making, let $inc(N\_SS_{T-t})$ be the sum of K_i for some period time (T-t) from the current time (t) to the running time (T). If $inc(N\_SS_{T-t})$ becomes less than 0, it induces that network signal strength is going to be downward. Therefore, we could predict that network disruption might occur.

Therefore,

Step 1. Finding $inc(N\_SS_{t-n})$ and $inc(N\_SS_{T-t})$

$inc(N\_SS_{t-n}) = \sum_{i=n}^{t} k_i$, where t= the currenttime (second) from the start time (n) of application.

$inc(N\_SS_{T-t}) = \sum_{i=t}^{T} k_i$, where T= the running time (second) from time (t).

Step 2. Making direct decision

Let ND be the network disruption.

When N_SS_t <=handoff threshold and $inc(N\_SS_{t-n}) < 0$,

$ND = inc(N\_SS_{T-t}) < 0$.

Step 3. Preparing network disruption

For mobile multimedia application services, the mobile device receives data until N_SS_t <= minimum acceptable signal strength.

With regard to the second context aware decision on mobile application services, we have to decide when the device should start to make preparation for gradual network disconnection based on network type, application bit rate, device type, device speed, and signal strength. The decision with above context information is called moderate decision. Since the coverage range is different between WiFi network and cellular network, network type has to be considered appropriately. For example, since WiFi network has shorter coverage range than cellular network, the device on movement in WiFi network needs earlier time than in cellular network for preparing network disconnection. Multimedia files are usually encoded at proper bit rate based on estimated/target network bandwidth or throughput for effective playback on mobile device. Therefore, application bit rate has to be considered appropriately. For example, applications with higher application bit rate need to prepare network disconnection earlier. Since each mobile device has different capacity for caching multimedia files, device type has to be considered appropriately. For example, mobile devices with high capacity need to prepare network disconnection earlier. Since the question how early the mobile device is getting out of coverage range is important fact for the second required decision, device speed has to be considered appropriately. For example, faster mobile device need to prepare network disconnection earlier. Table II shows context information for moderate decision making.

TABLE II: Other Context Information for Moderate Decision Making

Context	Dimension	Range	Abbreviation
Network	Signal strength	1~10	N_SS
	Type	WiFi=1, 3G=2	N_T
Application	Bit rate	Normal=1, Fast=2	A_BR
Device	Type	Normal=1, High=2	D_T
	Speed	Normal=1, Fast=2	D_S

Since N_T is directly proportional to the running time T, $T' = T \times N\_T$ should be applied, where T' is adjusted T with the value of contexts for the proper interval of comparison.

Since A_BR, D_T, and D_S are inversely proportional to the running time T, $T' = T \times (1/A\_BR) \times (1/D\_T) \times (1/D\_S)$ should be applied for the proper interval of comparison.

Therefore, $T' = T \times N\_T \times (1/A\_BR) \times (1/D\_T) \times (1/D\_S)$.

As we define the third and fourth decisions as intelligent decisions, intelligent decisions are prediction-based decision while the direct and moderate decisions are monitoring-based decision. Therefore, we need certain algorithms that reason from externally supplied instances to produce predictions. Table III shows context information for intelligent decision-1 that is the third required decision.

TABLE III: Contexts for Intelligent Decision-1

Context	Dimension	Range	Abbreviation
Network	Type	WiFi=1, 3G=2	N_T
Device	Speed	Normal=1, Fast=2	D_S
Environment	Location _Longitude	1~10	E_LL
	Location _Latitude	1~10	E_LLA

Intelligent decision-1 could be performed by probabilistic and Bayesian analytics, which is based on a probabilistic model of the observed data and prior knowledge and do general purpose probability estimation and inference with excellent accuracy in linear time and decision tree analytics, which is able to handle both continuous and categorical variables and provide a clear indication of which fields are most important for prediction or classification. After probabilistic and Bayesian analytics and decision tree analytics, we could draw out our own rule based on context information for intelligent decisions.

Predicted data on location longitude and latitude, which will be experienced with sudden network disconnection, are used for the process of intelligent decision-1.

The process of intelligent decision-1 making follows.

In order to avoid the momentary effect of a device's motion, we use an incremental method with relative distance (*D*) to the network disruption location similar to simple decisions and distance threshold. The distance threshold (*DT*) is defined as optimal distance at which to initiate a decision making.

If $D_i - D_{i-1} < 0$, let $K_i = 1$, where D_i is the distance from the network disruption location at time *i*.

Else if, $D_i - D_{i-1} > 0$, let $K_i = -1$

Else, $K_i = 0$

Let $inc(D_{t-n})$ be the sum of K_i for some time period (*t-n*) from the start time (*n*) of streaming application to current time (*t*).

Let $inc(D_{T-t})$ be the sum of K_i for some time period (*T-t*) from the current time (*t*) to the running time (*T*). When D_t is less than or equal to the distance threshold(*DT*) and $inc(D_{t-n})$ is less than zero, where D_t is the distance from the network disruption location at the current time *t*, it indicates that a device is going to experience sudden network disconnection if $inc(D_{T-t})$ becomes less than 0. Therefore, we could predict that network disruption might occur suddenly.

Therefore, Step 1. Finding $inc(D_{t-n})$ and $inc(D_{T-t})$

$$inc(D_{t-n}) = \sum_{i=n}^{t} k_i$$

, where *t*= time (second) from the start time (*n*) of application.

$$inc(D_{T-t}) = \sum_{i=t}^{T} k_i$$

, where *T*= the running time (second) from time (*t*) .

Step 2. Making intelligent decision-1

Let *ND* be the network disruption.

When $D_t \le DT$ and $inc(D_{t-n}) < 0$,

$ND = (inc(D_{T-t}) < 0)$.

Step 3. Preparing for network disruption

Requesting more data until = D_t are equal to minimum acceptable distance.

We define the fourth required decision, which is related with the question how we are able to know when the device should start to make preparation for sudden network disconnection as the intelligent decision-2. The intelligent decision-2 needs network type, application bit rate, device type, device speed, location longitude and location latitude as context information as mentioned earlier. Table IV shows context information for the intelligent decision-2.

TABLE IV: CONTEXTS FOR INTELLIGENT DECISION-2

Context	Dimension	Range	Abbreviation
Network	Type	WiFi=1, 3G=2	N_T
Application	Bit Rate	Normal=1, Fast=2	A_BR
Device	Type	Normal=1, High=2	D_T
	Speed	Normal=1, Fast=2	D_S
Environment	Location _Longitude	1~10	E_LL
	Location _Latitude	1~10	E_LLA

Since *N_T* is directly proportional to the running time *T*, *T'*= *T*× *N_T* should be applied for the proper interval of comparison same as multi-context based simple decision.

Since *A_BR*, *D_T*, and *D_S* have inverse proportion with the running time *T*, *T'*= *T*× *(1/A_BR)* × *(1/D_T)* × *(1/D_S)* should be applied for the proper interval of comparison.

Therefore, *T'*= *T* × *N_T*× (1/*A_BR*) × (1/*D_T*) × (1/*D_S*) has to be applied.

IV. EXPERIMENT AND EVALUATION

Our design and implementation incorporate with concerns of disconnection tolerant mobile application services. The mobile client uses HTC Dev Phone and Samsung Galaxy S that run on Android platform version 1.6 and version 2.1-updatae. The MIS uses IBM ThinkPad (T43) that runs on Ubuntu 8.04(Hardy Heron). Since Android supported multimedia formats (Video) are H.263, H.264 AVC and MPEG-4 SP, we decided to use the third party server for mobile multimedia application services on HP Compaq nx 6320 with Windows XP as the MIS. Fig. 2 illustrates the overview of experimental environment.

We design the prototype of mobile application services for demonstrating the feasibility of applying our proposed techniques. We implemented the mobile services transmitting using HTTP/TCP due to their widespread adoption for mobile device such as mobile handset and flexibility in implementation.

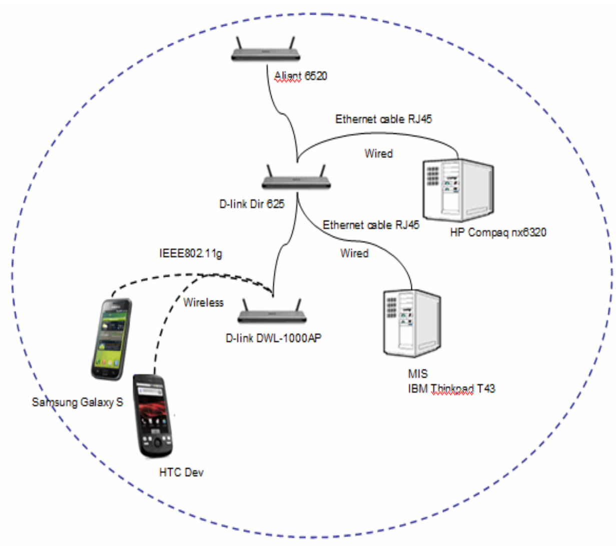

Fig. 2. Overview of experimental environment.

We analyze multimedia data (.mp4/11.3M) received without decision and with context aware decision in order to show how effectively and efficiently we could get data before network disconnection with higher sending rate.

For the experiment of intelligent decision-1, we used the direct decision for simplicity. Fig. 3 illustrates the comparison of total received data based on the change of sending rate using intelligent decisions from MIS.

In Fig. 3, the process (1) illustrates the total received data without decision. The process (2) illustrates the total received data with intelligent decision-1, which causes sending rate to be changed from sending rate 1 (15,630 KB/sec) to sending rate 2 (31,260 KB/sec). If the sending rate is higher, the total duration of data receiving time is shorter as we expected. Therefore, we could reserve more data before network disconnection. The comparison of decision processing time for intelligent decision-1 and intelligent decision-2 shows that the decision processing time has been reduced with fast device speed when device speed has been changed to 2 (fast).

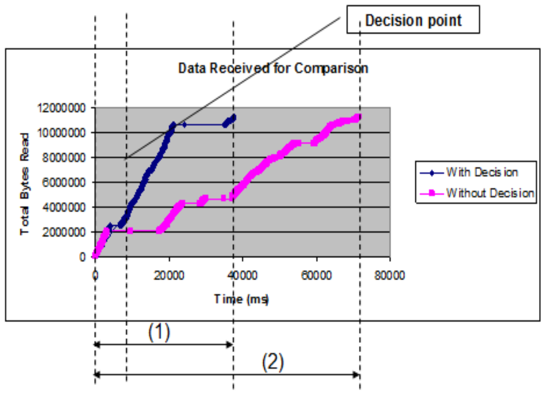

Fig. 3. Comparison of total received data using intelligent decisions.

For mobile interactive (ex. web) application service, we use public web sites. URL parsing has been made for the first sub level contents of current web document in the MIS when the CH on mobile device makes decision. Also, the MIS sends the contents of parsed URL to the mobile device.

In our experiment, the mobile device could obtain the first sub level contents of current web document before network disconnection so that the user may enjoy web services without undesirable termination during network disconnection period.

For mobile interactive (ex. game) application service, we use public game sites. The MIS obtains the information of current session for mobile device from application server and keeps this session during the network disconnection period. Therefore, after reconnection, the mobile device may resume the interactive service through the MIS.

V. Concluding Remarks

In this paper, we explore context aware intelligent decisions based on the proposed middleware architecture for disconnection tolerant mobile application services. The proposed approach could play an important role of supporting the service mobility for mobile application services.

For future work, we will further investigate on optimal algorithms to improve accuracy rate for decision making cases and user event patterns for the continuation of mobile interactive application services

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Sangwhan Cha received his B.S. in computer science from University of New Brunswick, NB Canada, in 2000, the M.S. in software engineering from Korea University, Seoul Korea, in 2007 and the PhD degree in computer science from University of New Brunswick, NB Canada, in 2012. He is a PostDoc fellow at faculty of computer science, University of New Brunswick. His research interests are in the areas of software engineering, mobile computing and intelligent system.

Weichang Du is a professor at faculty of Computer Science, University of New Brunswick since 1991. He obtained his PhD degree in Computer Science from University of Victoria in 1991. His main research areas include mobile and wireless computing, internet computing, software engineering and knowledge engineering.