Real-time Estimation and Analysis of Time-based Accessibility and Usability for Ubiquitous Mobile-Web Services

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Received November 17, 2010; revised December 1, 2010; accepted December 28, 2010; published May 31, 2011

Abstract

Ubiquitous web services have been expanding in various business areas with the evolution of wireless Internet technologies, accessible and usable with a variety of mobile Internet devices such as smart phones. Ubiquitous mobile-web information services can be evaluated for accessibility and usability with the mobile Internet devices interacting with mobile-web information servers. In human mobile-web activity, a web server could be a unified center for mobile-web interaction services as well as for real-time estimation and analysis of mobile-web interaction sessions. We present a real-time estimation and analysis scheme for time-based accessibility and usability in ubiquitous mobile-web services. With real-time estimation/analysis of sessions in a mobile-web server, we estimated the time-based accessibility and usability for comparison between different web services as well as for applications in mobile cloud computing services. We present empirical results based on the implementation of the real-time estimation/analysis scheme.

Keywords: Real-time estimation and analysis, accessibility, usability, interaction sessions

DOI: 10.3837/tiis.2011.05.004

1. Introduction

We have searched for a unified and ubiquitous web service for the simplification of information access interaction in an environment flooding with information. A ubiquitous web information service with a unified directory has been researched for efficient and usable interaction as well as for integrity of consistent information. As an example of a specific web application, we implemented a ubiquitous mobile-web information service with a unified name-based directory for social networking [1]. Social networks are “explicit representations of the relationships between individuals and groups in a community.” [2][3]. On the user side, people are increasingly using the Internet to establish virtual identities, social relationships, and communities [4]. Many social networking services (SNS) (e.g. Facebook, Twitter, etc.) using smart phones such as the iPhone and Android phone are proliferating rapidly around the world. A lot of application software is downloadable from the iPhone App-store, and mobile-web services are also expected to be a major trend of the mobile service. Instead of download-based mobile applications, we consider mobile-web service based on web standards such as the emerging HTML5.

The performance of a worldwide web service as a service platform became a central issue in providing a ubiquitous, reliable, and efficient information network for ubiquitous web information services. The client mobile devices for mobile-web information access have become very important for social networking interaction in ubiquitous mobile-web environments. The web server with a ubiquitous name-based directory, accessible ubiquitously with any Internet-capable device anytime and anywhere, plays a central role in mobile-web interaction for a ubiquitous mobile-web information service and real-time mobile-web activity analysis. For the performance of mobile-web information access using a web-based directory, we researched several perspectives (e.g. time-based accessibility and usability) regarding the web server for mobile-web interaction. Instead of a qualitative approach, we tried to estimate quantitative parameters of time-based accessibility and usability for the real-time analysis in the ubiquitous Internet environment.

We propose a real-time estimation/analysis of the time-based *accessibility* and *usability* in web activity for ubiquitous mobile-web information services with a ubiquitous mobile-web server. For worldwide *multilingual users*, we also searched to find a better way for the real-time information registration and search. Presenting the time-based accessibility and usability, we implemented a name-based mobile-web server/site (http://ktrip.net) to find rather familiar information used frequently such as web-based name cards, lecture bulletin boards, web-based phone numbers (of friends, relatives, or fellow alumni), and (mini/micro)blog URLs, as application examples of ubiquitous mobile-web services.

In the following sections, we introduce the background and related works; we present the real-time estimation/analysis for time-based accessibility and usability of web activity in the mobile Internet, especially with mobile-web interactions. We propose the time-based accessibility and usability of mobile-web interaction as real-time stochastic random variables. We present the implementation of realtime estimation/analysis with source codes of ‘global.asa’ in the http://ktrip.net server. We present empirical results (http://ktrip.net/display.asp) based on real-time estimation/analysis with the implementation of a ubiquitous mobile-web information service (http://ktrip.net), and present the time-based usability and number of active sessions. Finally, we will conclude our study with consideration of future works.

2. Background and Related Works

2.1. Web Interaction Activity

Facilitating communication and information processing, computers are regarded as tools that mediate between human actors and objects targeting an outcome. Having an important implication of social networking, this mediation is not merely between a person and the object, but also with other people. Tools are carriers of culture and social experience. The most important tenet of activity theory is its tool mediation concept [5].

Some researchers have studied building a context classification model based on activity theory [6]. Researchers have attempted to improve user interaction through the notion of context awareness by exploiting information relating to users, devices and environments. In many countries, better access to web services and web administration is becoming an important issue; and a few action lines of improvement for the Web Content Accessibility Guidelines have been suggested [7]. Universal access implies the accessibility and usability of Information Society Technologies (IST) by anyone, anywhere, anytime. Internet accessibility beyond disability was researched by Hofstader [8]. New approaches and related instruments are needed for meeting human requirements in this new reality. User activity patterns were researched on the basis of the real-time analysis of simultaneous activities [9]; for extraction of activity patterns, contexts were collected from physical sensors in a test-bed environment.

We implemented a ubiquitous mobile-web service with good accessibility and usability for w*eb interaction activity* in the ubiquitous Internet environment. We propose the time-based accessibility and usability for the real-time quantitative estimation/analysis with synthetic approach instead of analysis with various qualitative factors, considering w*eb interaction activity* among various human activities.

2.2. Accessibility and Usability

Accessibility and Usability guidelines have been set up to help designers in the process of creating usable and accessible sites [10]: W3C consortium recommendations for accessible web sites, the Web Accessibility Initiative (WAI) recommendations, and the Web Contents Accessibility Guidelines. We researched accessibility and usability of mobile-web interaction with multilingual domain names for a ubiquitous mobile-web service. We even tried to find unified and simplified parameters for comparison between different types of services. The W3C's Web Content Accessibility Guidelines 2.0 improves upon the initial standard, adopted in May 1999. WCAG 2.0 addresses problems that people with visual, auditory, physical, cognitive, and neurological difficulties caused by disabilities or age have in accessing the web. The new standard can handle material not written in HTML, it will work with all types of web content—including text, images, audio, and video—and all types of web applications—such as those for e-mail, e-commerce, financial management, authoring, and social networking. The standard alone won't deliver a fully accessible web. Even if web content conforms, user equipment may not be able to support accessibility [11]. *Accessibility* was studied on the basis of quantitative time metric [sec]; the usability has not been studied a great deal with a quantitative metric as researchers tend instead toward some qualitative evaluation. We propose the time metric for simplicity as a quantitative metric as well as for relative comparison between other homogeneous/heterogeneous services.

In a typical interactive information retrieval evaluation, typical outcome measures were usability and performance with offline analysis. Usability measures were based on searchers' responses to questionaire items or their interactions with the system, performance measures were based on the number of relevant document searchers found and the time it took them to do so [12]. Seffah et al. [13] studied usability in ISO standards, i.e. ISO 9241-11 (1998) and 9126-4 (2001), proposing that "*Usability* (focused on software) is generally a relative measure of whether a software product enables a particular set of users to achieve specified goals in a specified context of use. Usability can vary from one user to another and in general with the context of use, e.g. user profiles, task characteristics, hardware, software, and physical or organizational environments." Norman mentioned that the field of human–computer interaction (HCI) has long stressed interaction, but primarily through the study of the effectiveness of various means of constructing systems for a wide variety of activities and situations [14]. Effectiveness has been measured by such items as usability, understanding, the number of errors, and the amount of time required to complete a task. The definition of *usability* for mobile devices was referred [15] from of ISO 9241-11: "The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use." A system for automatically evaluating the accessibility and usability of web sites by checking their HTML code against guidelines has been studied by Beirekdar et al. [16]. We propose the *time-based usability* for quantitative comparison between different web.

Sutcliffe and Angeli [17] assessed interaction styles, i.e. traditional menu-based and interactive metaphors, in the web user interface, and they found that the menu-based interaction style was superior for usability and information quality. The usability of mobile devices and their applications is a key factor for the success of mobile computing. Betiol and Cybis [15] studied usability evaluation of mobile interfaces based on three different evaluation approaches; they mentioned the importance of the context of use of mobile devices in the usability evaluation, so that the traditional HCI evaluation criteria and methods should be reconsidered in order to meet the requirements of mobile interaction. There are now more browsers on mobile phones than on desktops, and there is a vast diversity in the types of devices; on top of this diversity, there is also the diversity required for accessibility [18].

Web site success is significantly associated with web site download delay, navigation, interactivity, and responsiveness [19]; metrics may be expanded to include pricing efficiencies, as well as identifying additional methods for measuring the interactivity and reponsiveness. There will be issues keyed to specific sites and designers will test usability directly with users, and specific metric measurement techniques can help the continuing process of improving web site design and testing.

A relatively large set of metrics have been introduced in the accessibility and usability literature. Instead of specific accessibility (e.g. web-contents accessibility), we propose the accessibility based on the time metric for the real-time estimation/analysis and comparison between different services. We also propose the time-based accessibility for the real-time estimation of usability as another random variable in the real-time estimation/anlysis.

2.3. Other Related Works

Tang et al. [20] studied a method of measuring the performance from the user's viewpoint, which can help enormously in making realistic assessment of true performance of database driven applications; the performance measurements were taken at user locations by using several specially designed JavaScript functions along with the ASP scripts. Server-centric interaction architecture for wireless application was presented by Saarinen et al. [21]; user interventions and input were minimized with server-initiated interactions. "When browsing information on large (even on smaller) web sites, users often receive too much irrelevant information. The vast amount of irrelevant information on most these web sites can overwhelm users, leading to the study about personalized web views for multilingual web sources," claimed Liu et al. [10]. Mobile devices have limited resources compared to desktops in terms of computing performance, network bandwidth, screen size for full browsing, etc., so there are many difficulties in providing support for mobile devices to fully use desktop-based web contents [22].

An approach to website personalization was introduced [23] on the basis of the exploitation of user browsing interests together with content and usage similarities among web pages; user-centered access was considered with some different user profiles. Some researchers [24] studied the relationship between user behaviors and user preference during web browsing on small screen devices to find user's interest blocks with offline statistical analysis. Many techniques and tools for validating web applications have been created, but none have attempted to leverage data gathered in the operation of web applications to assist with testing; the analysis of user-session techniques was suggested using captured user sessions [25]. Twitter is the hottest social medium around. The microblogging application enables anyone with Internet access to issue short public messages [26]. Twitter's search service does not consistently deliver real-time results: 20 or more minutes often pass before a given tweet appears in search results [27]. Some web sites such as news sites are checked very often, but others await their turn in a rotating schedule of visits by each crawler. For time-critical applications (e.g. real-time registration and advertisements) from the user's viewpoint, it takes a long time to register new information on a web site and be searchable by commercial portals (e.g. around 5 to 7days by Google, around 6 hours to 1 day by Yahoo, over one week by other portals in our experience).

The features of websites that we visit regularly differentiate them from websites that we do not visit. Forrester did some research on this as follows: good content (75%), usability (66%), speed (58%), frequency of updating (54%), (the rest is noise: 14% and lower) [28]. According to Pemberton's comment, "device independence, *accessibility* and *usability* are surprisingly closely related." By personalizing service discovery, users can find the most appropriate services for their immediate situation; Park et al. [29] studied to help mobile phone users find appropriate services according to their preferences and contexts. User interface proposed by us with a ubiquitous name-based directory must be convenient even for typing-in the domain names with mobile phones. Because the first step for web service with wired/mobile Internet (especially, with mobile Internet) is typing-in the domain name of the targeted web site offering the requested information or service.

The scheme for multilingual domain names has been standardized world-wide by IETF (Internet Engineering Task Force) and has been approved by ICANN (Internet Corporation for Assigned Names and Numbers). The auto-conversion functionality (i.e. from multilingual domain name to Puny code, or vice versa) for standardized multilingual domain name service has been embedded in the web browsers as a built-in functionality, e.g. from the version of MS IE7.0+, Firefox, Safari, Opera, and Google Chrome, etc. Puny code is a simple and efficient transfer encoding syntax; it uniquely and reversibly transforms a Unicode string into an ASCII string, and non-ASCII characters are represented by ASCII characters. UTF-8 can be used for URL encoding (different from the above multilingual domain name encoding). We researched the time-based accessibility and usability of mobile-web interaction with mobile phones, especially using a mobile-web directory accessible with many simple (single-character) multilingual domain names related to search keyword(s).

3. Real-time Analysis for time-based Accessibility and Usability

3.1. Consideration for Real-time Analysis

We considered the aforementioned concept about time-based accessibility and usability, and we focused on the real-time quantitative metric instead of qualitative metric. The parameters, i.e. time-based accessibility and usability, are stochastic random variables, and should be estimated in real-time for real-time evaluations of QoS (quality of service) or QoE (quality of experience). Depending on the phase of the software life cycle in which they are applied, usability metrics can be classified into one of two major categories, testing and predictive [13]; data from testing metrics are collected in order to measure the actual use of working service. We focused on time-based accessibility and usability as testing metrics in our research.

Jakob Nielsen [30] mentioned that "*accessibility* is not enough; the accessibility fallacy is the assumption that accessibility exists in a vacuum and can be scored without considering users and their tasks. Usability's job is to research user behavior and find out what works. *Usability* explains human behavior in complex systems under strongly context-dependent circumstances. On average, websites that try usability double their sales or other desired business metrics." Nielsen studied various types of usability (e.g. web usability, intranet usability, application usability, email usability, agile usability, mobile usability, donation usability, WAP usability, investor relations usability, etc.), however a comparison between different levels of usability is extremely difficult or not possible. We believe that usability is very relative and stochastically changing and is affected by other services/products because of the 24-hour time constraint in human activity. We tried to find the time-based usability as a common parameter for the real-time estimation and real-time comparison between different services. We present a real-time estimation and analysis scheme for the time-based accessibility and usability of mobile-web interaction server http://ktrip.net, accessible with single-character multilingual domain names (e.g. converted ASCII Puny code format: 'http://xn--ypd.net', 'http://xn--4pd.net', etc.) as single-character keys in a name-based directory service.

Activity theory posits that an activity is meaningful with actions [5], and actions are meaningful with operations; activities, actions, and operations are not static structures. We considered the activity (e.g. goal is to publish and search specific information using the mobile Internet), actions (e.g. some sessions with mobile phone), and operations (e.g. real-time interactions). The session information is stored on the web server using the session identifier (session ID) generated as a result of the first request from the end user running a web browser. Session management is the process of keeping track of a user's activity across sessions of interaction with the computer system. Real-time estimation/analysis based on a web session (i.e. HTTP session) in a web server was the focus in our research.

We propose the important parameters of time-based accessibility and usability with mobile-web interactions from the user's perspective. They are stochastic random variables, and we need to estimate them in real-time way for the real-time analysis (e.g. real-time comparison of large scale web sites about time-based accessibility and usability). We analyzed the time-based random variables with the time metric, mainly with the spent time by user and the input time on keypads for domain name(s), URL(s), search keyword(s) and contents in the user-centric mobile-web interactions.

For example, for a mobile user in **Fig. 1**, we assume that a random variable, the interaction time as a user's interaction in a session, from a user to the contents in DB through mobile Internet in the forward interaction with a mobile phone is I_F. That is composed of the preparation time for any user in the ubiquitous Internet environment to use a mobile device for interaction in his/her hand is I_u. The time spent by the user with the mobile device to make the appropriate interaction for service is I_m. The aggregate interaction time to the mobile-web server after the mobile device through mobile Internet for mobile service is I_w, and the network time is embedded here. The interaction time depending upon mobile contents is I_c. We researched the time-based accessibility as well as the time-based usability for mobile-web information services on the basis of the real-time estimation of stochastic random variables. The session time based on interactions is dependent on this content retrieval or registration, and there are several back and forth iterations during the session. The backward interaction time in the session, from the content retrieval time to the requesting user through a web server and the mobile Internet using a mobile device, is $\boldsymbol{I_B}$. A single complete interaction time, $\boldsymbol{I_1}$, is the summation of $\boldsymbol{I_F}$ and $\boldsymbol{I_B}$.

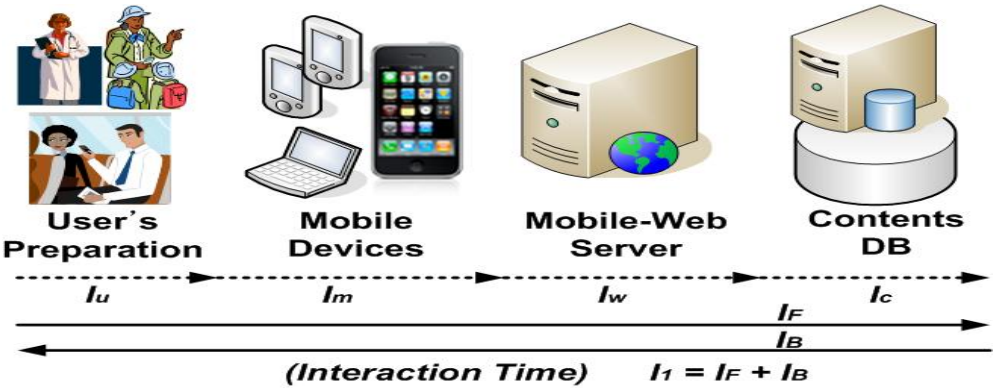

Fig. 1. An Interaction Time in a Session of Mobile-Web Activity

3.2. Web Interaction in Web Activity

In the previous **Fig. 1**, we showed a simple example with a single interaction. However there are actually several interactions in a session as shown in **Fig. 2** below.

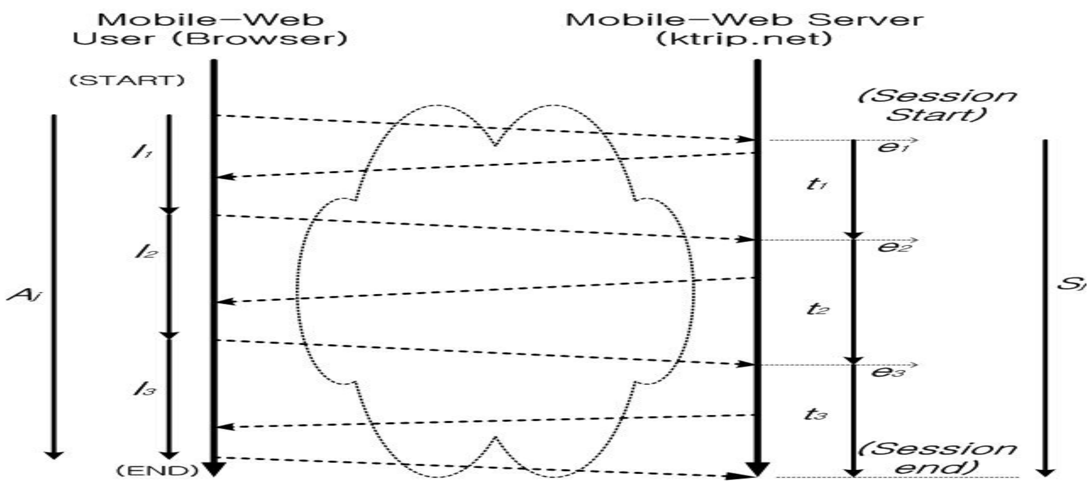

Fig. 2. Mobile-Web Interactions in a Session in Mobile-Web Activity

Fig.2 shows the interaction sequence such as accessing ktrip.net ($\boldsymbol{I_1}$) with the iPhone Safari browser, reading a title/name-card list, reading the contents ($\boldsymbol{I_2}$) after clicking a listed title in ktrip.net (mobile-web), then finishing the session (***I_3***) after closing the browser. On the ktrip.net server/site, we can estimate in real-time the interaction time of the mobile-web activity with variation depending upon network/server condition. We present the time-based *accessibility* and *usability* in mobile-web interaction service; a service must be *accessible* for the service to be *usable*. We present the time-based accessibility in a session, and then we will present the time-based *usability* based on the time-based *accessibility* and the usage frequency.

We proposed the stochastic random variables, time-based *accessibility* and *usability* in mobile-web interaction service. If a service is more usable, then more sessions will be made; the number of created sessions per a second, which we define as a usage frequency, is correlated to the usability. We propose that *time-based accessibility* is the *completion time of a session*; that is different from the web-contents accessibility, which cannot show the completion time of an action (i.e. a session) of using the web-contents. We now will discuss the time-based accessibility estimated in a session at the mobile-web interaction server. Next, we will discuss the *time-based usability* based on the *time-based accessibility* and the usage frequency. We tried to find fundamental parameters based on time [sec] metric for simplification and comparison between other web services. The real-time estimation of the stochastic random variables, i.e. time-based *accessibility* and stochastic *usability*, is presented on the basis of the real-time time-series analysis on the server side instead of the user side.

3.3. Real-time Estimation of Time-based Accessibility

In **Fig. 2**, the time interval between event ***e_2*** and event ***e_1*** is $t_1 = e_2(t) - e_1(t)$, which can be estimated in real-time with the implementation in application programs at a web interaction server. Similarly, the time interval between event ***e_3*** and event ***e_2*** is $t_2 = e_3(t) - e_2(t)$. We can estimate and retrieve statistics of random variables (i.e. t_1, t_2…). The number of user interactions in a session can be estimated with the incoming events in application programs at the mobile-web interaction server.

For the real-time estimation of time-based random variables, we define the time interval between incoming events for ***i_{th}*** interaction in a session (estimated at a mobile-web server), ***t_i***. The overall session duration time for a ***j***th session in information access is $S_j = \sum_{i=1}^{n} t_i$, where n is the number of interactions (***I_1***, ***I_2*** … at user-side) or incoming events (***e_1***, ***e_2*** … at server-side) in a session. ***S_j***, which is a session duration time, is related to the time-based *accessibility* [sec] [("how fast to complete a session")] for a mobile-web interaction activity in our presentation.

For the real-time estimation the session duration time could be estimated consistently on the basis of easy implementation in the programs (such as the ASP, JSP, or PHP) running in the web server, instead of estimation on the user-side. For the implementation, instead of estimation of each individual event (***e_1***, ***e_2***, …) or each time interval (***t_1***, ***t_2***, …), whole session duration time is easy to estimate with the global.asa program. The global.asa program (e.g. with the ASP program in MS IIS server) is the recommended place to estimate in real-time with a simple implementation, and we present in the following sections.

$$\textit{(time-based) } \boldsymbol{A}\textit{ccessibility} = A_j \approx \sum_{i=1}^{n} t_i \approx S_j \ \textit{[sec]} \qquad (1)$$

For real-time mobile-web interactions in the wireless Internet environment, the equation (1) is less accurate because of the unpredictability of the network. We assumed that the *time-based accessibility* would be dependent on the condition of the network reliability, the server condition and the user's interaction behavior.

The right place for the real-time estimation/analysis is proposed considering the requirements and implementation based on the server program. For example, the *global.asa* ASP web server program is the right place for a simple implementation of the real-time estimation/analysis of session (action) time and usage frequency (i.e. number of actions within a time period).

3.4. Real-time Estimation of Stochastic Usability

The number of total sessions by users or clients in a mobile-web site can be estimated with statistics for the stochastic usability evaluation. The *time-based usability*, which should be estimated in a real-time way as a quantitative parameter (i.e. "How usable is the web site per day?"), could be defined with the equation as follows:

$$\textit{(time-based)}\ \boldsymbol{U}\textit{sability} = \sum_{j=1}^{f} A_j \qquad (2)$$

where f is the number of daily sessions by the same or different users, i.e. usage frequency per day (or 24 hours). The f is random variable related to usage of a service (e.g. Google search, Twitter, etc.) by a user, by a community, or by any group. $\boldsymbol{A_j}$ is the accessibility in j_{th} session (action) for a web activity in a day, therefore the time-based usability is the daily (or hourly, weekly, monthly, yearly as an interested period) summation of the accessibility, as follows:

$$\textit{(time-based)}\ \boldsymbol{U}\textit{sability} = \sum_{j=1}^{f} A_j \approx \overline{A} * \overline{f} \qquad (3)$$

For simplicity in our discussion, the time-based (per second, per hour, per day, per week, per month or per year) *usability* as a stochastic random variable could be asymptotically approximated with the multiplication of the *mean* (i.e. average) of time-based *accessibility* ***A*** *[sec]* and the *mean* of usage frequency ***f*** [1/sec]. In equation (3) the magnitude without dimension is dependent on the dimension of frequency ***f***, which we used with "per second" (i.e. [1/sec]) in our implementation discussed in the following section. The greater the value of time-based *usability* [sec] is, the more usable the web service (activity) for a user or group is on the basis of time.

With this concept, we can compare the *time-based usability* between different types of service. For example, the usability of Google for a specific user as well as worldwide users can be compared to the time-based usability of Twitter for a specific user and worldwide users, on the basis of the real-time/offline analysis depending upon the implementation. We found that the time-based accessibility and usability are not constant and they are stochastically changing random variables. The other services or activities are affecting the stochastic usability, and new services or other activities may affect the time-based accessibility including the stochastic usability of a specific user or user groups (e.g. various communities).

3.5. Real-time Estimation of Mean (Average)

The time-based accessibility and usability (Equation (1) and (2)) could be used for both the offline analysis and the real-time analysis. We present the real-time estimation of statistics (e.g. time-based accessibility, time-based usability, usage frequency). For the real-time estimation, we used an exponentially weighted moving average model [31] with the smoothing parameter α (we used 0.1 in our simplified implementation of real-time estimation, i.e. giving 10% weight to the most recent sample and 90% weight to the recent average with our mobile-web experience) to get the mean value of the random variables (i.e. time-based accessibility and usability). The *mean (i.e. average)* value of *Accessibility*: $\overline{A_k}$, required for the real-time estimation can be estimated with a smoothing model as follows:

$$\overline{A_k} = \alpha A_k + (1-\alpha)\overline{A_{k-1}} \text{ where } 0 < \alpha < 1 \tag{4}$$

$$\overline{A_k} = 0.1 * A_k + 0.9 * \overline{A_{k-1}} \text{ when } \alpha = 0.1 \tag{5}$$

Time-based Usability can be estimated approximately as follows:

$$\textit{(time-based) Usability} = U_k \approx \overline{A_k} * \overline{f_k} \tag{6}$$

In another way, the *mean (i.e. average)* value of time-based *Usability*: $\overline{U_k}$, for the real-time estimation can be estimated or forecasted (if we need) as follows:

$$\overline{U_k} = \alpha U_k + (1-\alpha)\overline{U_{k-1}} \text{ where } 0 < \alpha < 1 \tag{7}$$

$$\overline{U_k} = 0.1 * U_k + 0.9 * \overline{U_{k-1}} \text{ when } \alpha = 0.1 \tag{8}$$

$$\overline{U_k} = 0.1 * (\overline{A_k} * \overline{f_k}) + 0.9 * \overline{U_{k-1}} \text{ when } \alpha = 0.1 \tag{9}$$

With our mobile-web experience in real-time estimation of statistics, we used a value 0.1 as a smoothing parameter in our implementation of real-time estimation, i.e. giving 10% weight to the most recent usability sample and 90% weight to the recent average of usability.

4. Implementation and Empirical Results

4.1. Implemented Source Code for Real-time Estimation/Analysis

Fig. 3 shows sessions on a time axis, we estimated many aspects of sessions in a web server. In the global.asa program in on the http://ktrip.net server, *max/min* sesssion duration time, starting/ending time of sessions, *inter-arrival* time between adjacent sessions, etc. could be estimated in real-time for the real-time estimation of *time-based accessibility and usability* of a specific web server site. A greater number of sessions implies more test preparation and execution time; techniques for filtering sessions, such as the reduction and clustering techniques [25] were suggested and can be considered in our research.

We used continuous sample sessions (**S**) for the real-time estimation of time-based accessibility and usability as shown in **Fig. 3**; we propose this sampling scheme as a reduction technique of samples, and we present the empirical results in the following section. We estimated in real-time the statistics (i.e. *mean, max/min of session duration*) with sampled sessions, and we estimated the statistics of the inter-arrival time (to get the usage frequency based on fast tracking) with all sessions on http://ktrip.net, as shown in **Fig. 3**.

The following source codes of global.asa in the ktrip.net server were implemented for the real-time estimation of stochastic random variables, i.e. *time-based accessibility*, *time-based usability*, usage frequency, etc. Statistics for *mean*, *max/min* value of each stochastic random variable are estimated in real-time. Equations (1), (5), (6), (9) in the previous section have been implemented in the following program with estimated parameters (*mean*: "*mean*A") and "U"). Another estimated parameter ("*mean*TimeInterval") is to estimate a usage frequency based on inter-arrival time between continuous sessions.

```
<script language="vbscript" runat="server">
Sub application_onStart
            '---initialize Cumulative Session Counter
```

```
        '---initialize Current Session Counter
        ………..(Omit)………………
End sub
Sub session_onStart
        …….. (omit)…………….
Application("MeanCurrentSes")=0.1*Application("CurrentSes")+0.9*Application("MeanCurrentSes")
Application("sid")=Session.SessionID
Application("meanTimeInterval")=0.1*DateDiff("s",Application("timep"),now)+
                        0.9*Application("meanTimeInterval")
        …….. (omit)……………
End sub
Sub session_onEnd
        …….. (omit)…………….
Application("A")=Application("SessionDurationTime")
Application("meanA")=0.1*Application("A") + 0.9*Application("meanA")
Application("U_fast")=Application("meanA")/Application("meanTimeInterval")
Application("U_slow")=Application("meanA")*Application("meanF")
Application("meanU_slow")=0.1*Application("meanA")*Application("meanF") + 0.9Application("meanU_slow")
Application("meanU_fast")=0.1*Application("meanA")/Application("meanTimeInterval") +
                      0.9Application("meanU_fast")
        …….. (omit)…………….
End sub
</script>
```

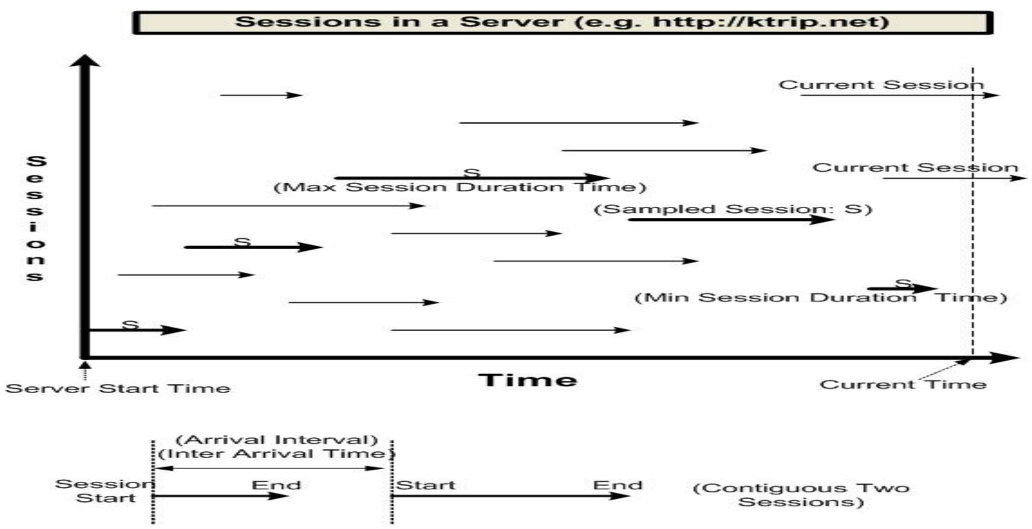

Fig. 3. Sessions in a Server (ktrip.net) with Time Axis

4.2. Empirical Results based on Real-time Estimation/Analysis

Within the above programs ktrip.net/global.asa and alltrip.net/global.asa for two web sites: http://ktrip.net and http://alltrip.net, many interested parameters can be estimated in real-time. Then, with the following programs: http://ktrip.net/display.asp and http://alltrip.net/display.asp, the estimated statistics of interested parameters can be displayed on the screen at anytime and anywhere.

```
<body>
…….. (omit)…………….
Start time of Server <%=Application("serverdate")%>   <br>
Mean Current Number of Sessions=<%=Application("MeanCurrentSes")%> <br>
Mean Accessibility=<%=Application("meanA")%> [sec] <br>
```

```
Usability(fast tracking)=<%=Application("Ufast")%>  <br>
Mean Usage Frequency(fast tracking)=<%=1/Application("meanTimeInterval")%> [per sec]  <br>
Mean Usage Frequency(slow tracking)=<%=Application("F")%> [per sec]  <br>
Mean Inter-arrival Time between Sessions=<%= Application("meanTimeInterval")%> [sec] <br>
…….. (omit)…………….
Current Session ID=<%=Application("sid")%> <br>
Maximum Accessibility= <%=Application("Amax")%>  [sec]<br>
Minimum Accessibility= <%=Application("Amin")%>  [sec]<br>
Maximum Usability(fast)= <%=Application("Ufastmax")%> <br>
Minimum Usability(fast)= <%=Application("Ufastmin")%> <br>
…….. (omit)…………….
</body>
```

In **Table 1**, the following results (no. 1~34) for a ubiquitous mobile-web site (http://ktrip.net: A), which is accessed more frequently (*mean* inter-arrival time: 1.6~52.77 [sec] as shown at no. 23/24 in **Table 1**) and more usable than another web site (http://alltrip.net: B), are displayed in real-time in the URL: http://ktrip.net/display.asp. These empirical results are displayed around 2010-10-20 PM 2:24, and the global.asa program started around 2010-10-18 PM 2:26:38. Results (no. 1~34) for a web site (http://alltrip.net: B), which is not accessed frequently (i.e. less usable; *mean* inter-arrival time: 93.2~2,205.94 [sec] as shown at no. 23/24 in **Table 1**), are displayed in real-time in the URL: http://alltrip.net/display.asp. The two web sites (ktrip.net and alltrip.net) are running on the same web server computer.

Each parameter for the real-time estimation of empirical data is explained as follows: A1 (i.e. no. 1 for ktrip.net: A) is for the cumulative total number of sessions, A2 is for currently active (i.e. in use) number of sessions, A3 is for the *mean* number of recently active sessions, A4 is for the starting time of server (or global.asa), A5 is for the current *mean* of *time-based Accessibility*, A6 is for the current *mean* of usage frequency of sessions based on the reciprocal of *mean* inter-arrival time (A10) between continuous sessions (for fast tracking *Usability*), A7 is for the current *time-based Usability (fast tracking)*, A8 is for the current *mean* of usage frequency of sessions based on the average from starting time of server (for slow tracking *Usability*), A9 is for the current *mean* of *time-based Usability (slow tracking)*, A10 is for the current *mean* of inter-arrival time between continuous sessions, A11 is for the starting time of a front-session among the recent sessions, A12 is for the starting time of a following back-session among the recent sessions, A13 is for the current number of completed sessions, A14 is for the current number of actually sampled (for real-time estimation of session duration time, i.e. accessibility) sessions, A15 is for the current accessibility (i.e. session duration time), A16 is for the starting time of actually sampled (recent) session, A17 is for the ending time of actually sampled (recent) session, A18 is for the current session ID, A19 is for the maximum number of simultaneously active sessions, A20 is for the minimum number of simultaneously active sessions, A21 is for the maximum *mean* of simultaneously active sessions, A22 is for the minimum *mean* of simultaneously active sessions, A23 is for the maximum *mean* of inter-arrival time between continuous sessions, A24 is for the minimum *mean* of inter-arrival time between continuous sessions, A25 is for the maximum value of inter-arrival time between continuous sessions, A26 is for the minimum value of inter-arrival time between continuous sessions, A27 is for the maximum value of *mean* accessibility, A28 is for the minimum value of *mean* accessibility, A29 is for the maximum value of usability (fast tracking), A30 is for the minimum value of usability (fast tracking), A31 is for the maximum value of *mean* usability (slow tracking), A32 is for the minimum value of *mean* usability (slow tracking), A33 is for the maximum accessibility (i.e. session duration time), A34 is for the minimum accessibility (i.e. session duration time). B1~ B34 for another web site http://alltrip.net are compared with the A1~A34 for http://ktrip.net, which is a ubiquitous mobile-web server/site.

Table 1. Stochastic Parameters from Real-time Estimation/Analysis (after 48 hours)

no	Real-time Estimation Parameter	ktrip.net (A)	alltrip.net (B)	Unit
1	Cumulative Total Number of Sessions	8,899	175	
2	Number of Current Active (in use) Sessions	12	2	
3	Mean Number of Active (in use) Sessions	11.3	0.77	
4	Start Time of Server	‘10-10-18PM2:26:38	‘10-10-18PM2:32:24	
5	Mean Accessibility	159.45	89.98	sec
6	Mean Usage Frequency (fast tracking)	0.085	0.0018	1/sec
7	Usability (fast tracking)	13.6	0.16	
8	Mean Usage Frequency (slow tracking)	0.052	0.001	1/sec
9	Mean Usability (slow tracking)	7.94	0.088	
10	Mean Inter-arrival Time (between Sessions)	11.8	540.58	sec
11	Front Session (recent) Starting Time	‘10-10-20PM2:23:38	‘10-10-20PM2:25:39	
12	Back Session (recent) Starting Time	‘10-10-20PM2:23:42	‘10-10-20PM2:26:32	
13	Number of Completed Sessions	8,887	173	
14	Number of Sampled Sessions	928	146	
15	Accessibility (Session Duration Time)	179	95	sec
16	Session (sampled) Starting Time	‘10-10-20PM2:18:39	‘10-10-20PM2:2:49	
17	Session (sampled) Ending Time	‘10-10-20PM2:21:38	‘10-10-20PM2:4:24	
18	A Current Session ID	720483364	720483386	
19	Max Number of Active (in use) Sessions	56	6	
20	Min Number of Active (in use) Sessions	1	1	
21	Max Mean Active (in use) Sessions	50.3	2.6	
22	Min Mean Active (in use) Sessions	1	0.47	
23	Max Mean Inter-arrival Time	52.77	2,205.94	sec
24	Min Mean Inter-arrival Time	1.6	93.2	sec
25	Max Inter-arrival Time (between Sessions)	244	7,325	sec
26	Min Inter-arrival Time (between Sessions)	0	0	sec
27	Max Mean Accessibility	216.28	154	sec
28	Min Mean Accessibility	120	84.48	sec
29	Max Usability (fast tracking)	95.3	6.29	
30	Min Usability (fast tracking)	0	0	
31	Max Mean Usability (slow tracking)	8.86	1	
32	Min Mean Usability (slow tracking)	6.14	0.082	
33	Max Accessibility (Session Duration Time)	655	173	sec
34	Min Accessibility (Session Duration Time)	64	60	sec

Above, **Table 1** shows the recent statistical results (88 random samples among 8,899 sessions) with 8,899 sessions (from sequential session number: 1 to 8,899) of ktrip.net server as well as with 170 sessions of alltrip.net server at 48 hours after the starting time of the servers (i.e. ktrip.net and alltrip.net). From **Table 1**, we can observe 12 active (not completed yet) sessions (as shown in A2) and 928 sampled sessions (as in A14) among 8,887 completed sessions (as in A13) from 8,899 total sessions (as in A1) in ktrip.net(A). We can also observe 2 active (not completed yet) sessions (as shown in B2) and 146 sampled sessions (as in B14) among 173 completed sessions (as in B13) from 170 total sessions (as in B1) in alltrip.net(B). We focus on the real-time estimation/analysis. We can observe the maximum inter-arrival time, A25 (244[sec]) for ktrip.net and B25 (7,325[sec]) for alltrip.net), because the ktrip.net server/site is more useful than alltrip.net. We can also observe the maximum session duration time (i.e. accessibility) of A33 (655[sec]) for ktrip.net and B33 (173[sec]) for alltrip.net.

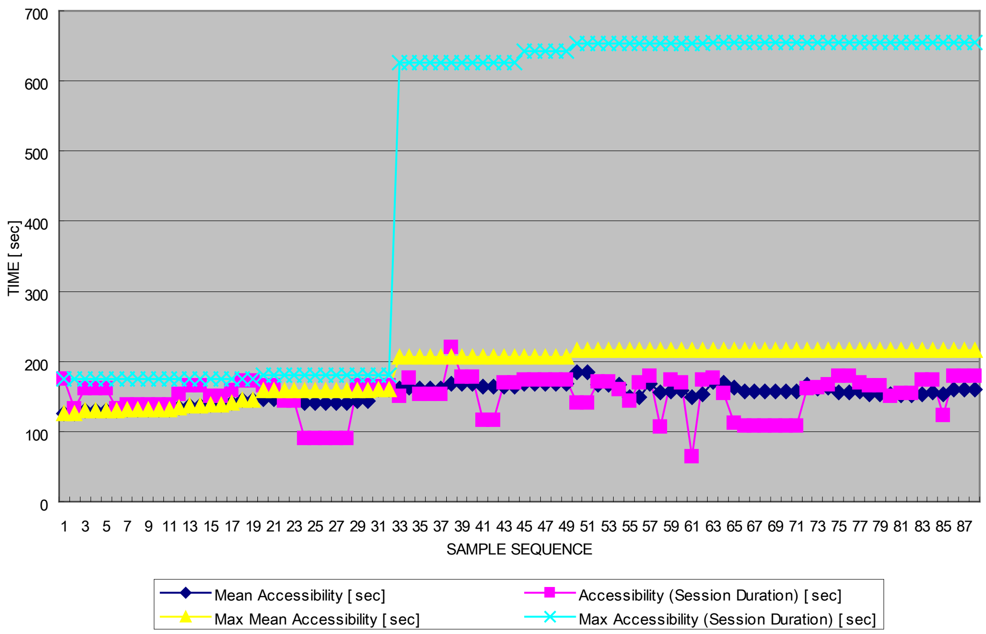

Fig. 4. Real-time Estimation of Mean Accessibility (Session-duration Time) (in ktrip.net)

In **Fig. 4** with the maximum value of accessibility (i.e. session duration time), between sample no. 32 (sequential session number: 489 in the 8,899 sessions) and 33(sequential session number: 1278) among 88 samples, there is rapid increase of accessibility (i.e. session duration time: 626 [sec] compared to the prior maximum session duration time: 180[sec]) in ktrip.net server/site. We found that the rapid increase of the session duration time is caused by the rapid increase of active number of sessions (24/19.8 as max/*mean* number of sessions in the sample no. 32, 49/42 as max/*mean* number of sessions in the sample no. 33) between the two sequential session numbers (489 and 1278 among 8,899 sessions). In **Fig. 5**, the minimum *mean* inter-arrival time approached to 3.02 [sec] from 5.42 [sec] between the two sample no. 32 and 33, therefore the increased number of sessions affected the accessibility (i.e. session duration time).

4.3. Time-based Usability and Number of Sessions

We foussed on the estimation/analysis for the time-based usability related to ktrip.net(A) in **Table 1**, because the ktrip.net site is more frequently accessed by users and we can analyze with more useful/meaningful data. From the previous equation (6), we could estimate the usability, which is dimensionless and stochastic random variable. We have tried to find the implications of the stocahstic usability. We found that the time-based usability is strongly related to the number of active sessions in a web server/site (e.g. ktrip.net in our case). In the following **Fig. 6**, we show the relationship between the time-based usability and the active number of sessions in a web server/site at an arbitrary moment. We found the following relationship between the usability for fast tracking (13.6 in A7, **Table 1**) and the number of current active sessions (12 in A2, **Table 1**) in a mobile-web server/site (ktrip.net) at a moment of time.

$$Usability: U_k \approx \overline{A_k} * \overline{f_k} \approx Number-of-Sessions \quad (10)$$

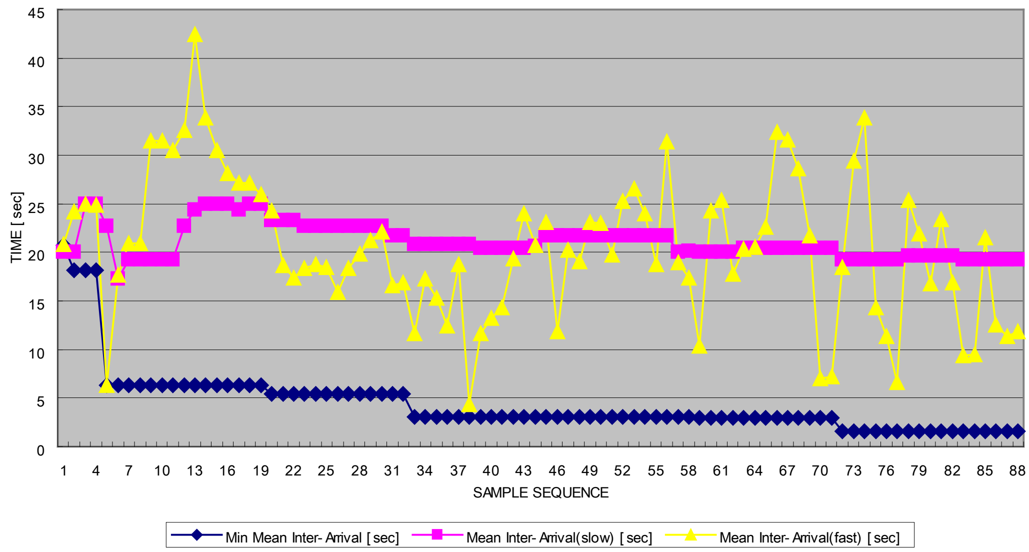

Fig. 5. Mean Inter-Arrival Time between Sessions (in ktrip.net)

In **Fig. 6** with usability and number of active (in use) sessions, between the sample no. 37 (sequential session number 1299 in the 8,899 sessions) and 38 (sequential session number: 1324) among 88 samples, there is rapid increase of usability (from 8.58 to 38.56). In **Fig. 5**, we found that the rapid increase is caused by *mean* inter-arrival time (18.79 [sec] in the session number 1299, 4.35 [sec] in the session number 1324) between the two sequential session numbers (1299 and 1324; i.e. the sample no. 37 and 38). If the arrival rate (i.e. the reciprocal of *mean* inter-arrival time) approached to the increased rate, then the session duration time (i.e. the time-based accessibility; from 153[sec] to 220[sec]) and the time-based usability increased (from 8.58 to 38.56) with the increased number of sessions (from 14 to 24) with the proposed estimation model in ktrip.net server/site.

In **Fig. 7** with maximum value of usability and number of sessions, between sample no. 71 (sequential session number 7230 in the 8,899 sessions) and 72 (sequential session number 7945) among 88 samples, there is a rapid increase of *maximum* usability (from 53.4 to 95). In **Fig. 5**, we found that the rapid increase is caused by minimum *mean* inter-arrival time (2.96 [sec] in the session number 7230, 1.6 [sec] in the session number:7945) between the two sequential session numbers (7230 and 7945; i.e. sample no. 71 and 72). If the arrival rate (i.e. the reciprocal of *mean* inter-arrival time) increased and the session duration time (i.e. the time-based accessibility; from 157[sec] to 166.6[sec] in the sample no. 71 and 72) increased, then the time-based usability increased (from 53.4 to 95) more than the increase of the maximum number of active sessions (from 49 to 56) in ktrip.net server/site. We need further research for the refined improvement of our real-time estimation/analysis model, especially in the critical region (e.g. near maximum capacity of number of active sessions and heavy inter-arrival rate, etc).

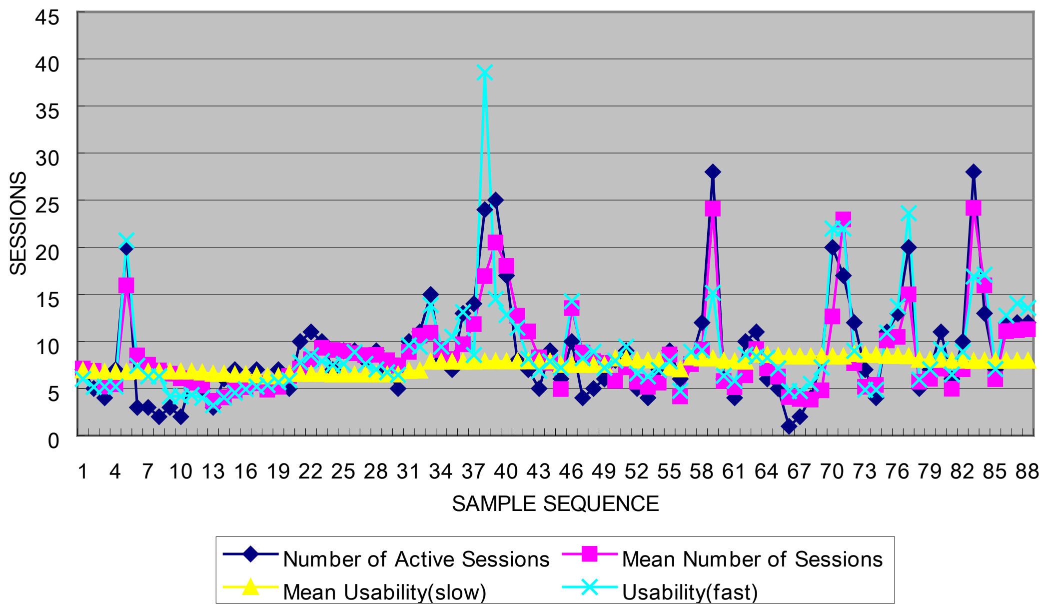

Fig. 6. Usability and Number of Active (in use) Sessions (in ktrip.net)

In **Fig. 8** with *mean* usability and *mean* number of active (in use) sessions, between the sample no. 5 (sequential session number: 48 in the 201 sessions) and no. 6 (sequential session number: 58) among 74 samples, there is rapid increase of usability (from 17.92 to 37) and maximum usability (from 32.3 to 38.05). We found that the rapid increase is caused by *mean* inter-arrival time (7.43[sec] to 4.7[sec]) between the two sequential session numbers (48 and 58; i.e. the sample no.: 5 and 6). In the **Fig. 8**, we showed the relationship between the time-based usability and the active number of sessions. We can compare the *mean* value of the time-based usability and the *mean* value of active sessions. We found the following relationship (equation (11)) between the *mean* usability and the *mean* number of sessions in a web server/site (ktrip.net) at a moment of time; we need further research for refinement of proposed estimation model with the trade-off analysis between the accuracy of real-time estimation and the complexity of implementation.

$$\textit{Mean Usability: } \overline{U_k} \approx \overline{\overline{A_k}} * \overline{f_k} \approx \overline{Number-of-Sessions} \tag{11}$$

The limitation of our proposed usability is determined by the aggregate value of time-based accessibility with usage frequency (slow/fast tracking). The formula (i.e. equations (1) through (11)) and **Fig. 3** put the same weight for sessions generated by the same user and sessions generated by different users. Depending upon the scheme of web-browser cache-time control by server program (e.g. response.expires value in ASP program), the abnormal multiple (sequential) sessions generated by a single user may be prevented within a controlled cache-time of an Internet browser. However we have not differentiated the types of session creations by a single user, multiple users or web crawlers in our research, and we leave the time-based usability related to the characteristics of session creation as a further refinement of our research. We can define the *session traffic intensity* as the ratio of session arrival rate to the maximum arrival rate at a web server. We leave these research issues depending upon the characteristics of session creation for further research.

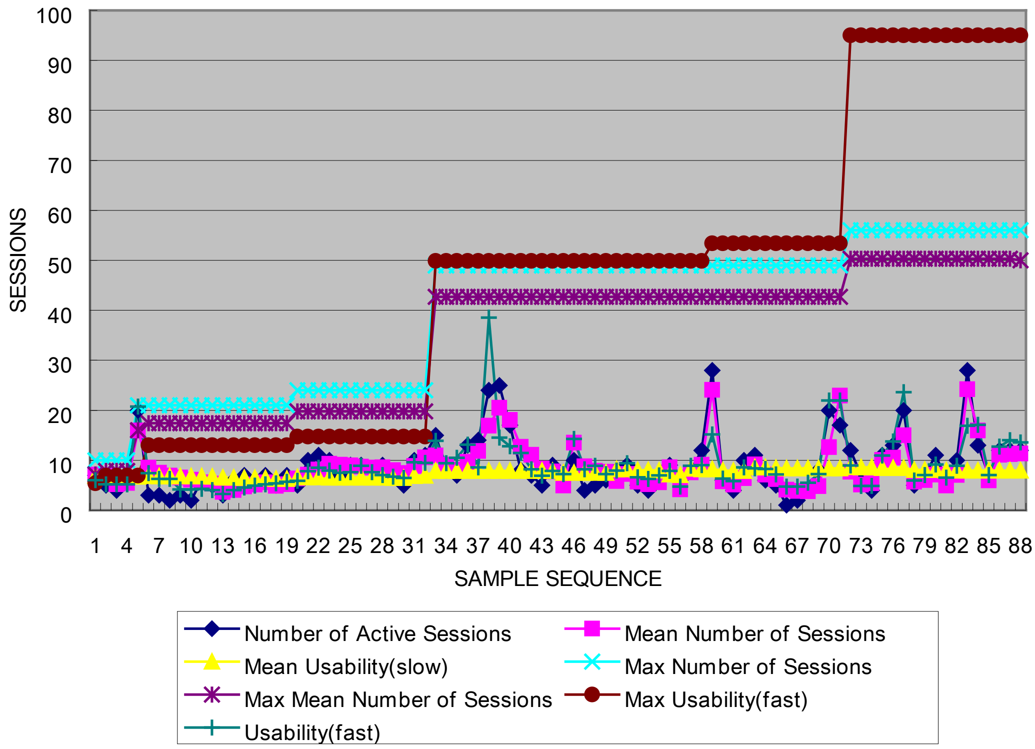

Fig. 7. *Max* Usability and *Max* Number of Active Sessions (in ktrip.net)

If we know the experienced maximum arrival rate (as a QoE parameter), which the web server can operate with a number of active sessions and acceptable accessibility for QoS (needs further research), then we can detect or forecast the situation of the beginning time of over capacity of a web server. We will research the control scheme to protect the web server from over capacity as a further research issue, because such over-capacity problems have been happening so frequently in rapidly growing web-based services such as Twitter. If we know two values: the time-based accessibility and inter-arrival rate (i.e. usage frequency), then we can estimate the number of current active sessions in a web server. For a mobile cloud computing service, the mean value of the usability statistics can be used for cost analysis for billing by a service provider. The billing scheme of advertisement in a specific web server will be researched further.

As a summary of implementation, the web server (ktrip.net) was developed for ubiquitous mobile-web information services. For multilingual users, we implemented a mobile-web server with a name-based directory accessible with a multilingual single-character domain name's ASCII Puny code, e.g. xn--ypd.com, etc; the Puny code is for multilingual domain names and different from UTF-8 for URL. Performance measurement of DB-driven network applications was presented from the user's viewpoint [20] with JavaScript and ASP scripts.

We focused on the implementation with server script (e.g. the ASP) instead of client-side JavaScript in the real-time estimation and analysis of time-based *accessibility* and *usability* for ubiquitous mobile-web services. As an example of ubiquitous mobile-web information services with various mobile phones serviced by many mobile service operators, we used the ASP server program based on Microsoft IIS web server and DBMS. With this application program and the global.asa for real-time estimation/analysis, the *ktrip.net* server/site can be accessed in a unified way by different mobile phones for mobile-web interaction with a quantitative service level of time-based accessibility and usability.

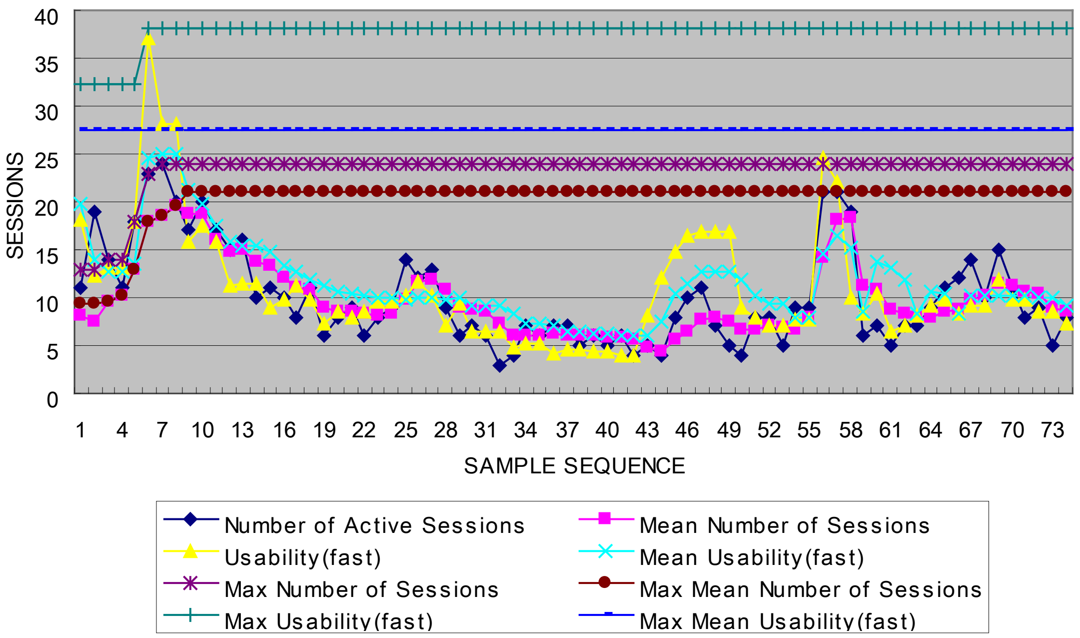

Fig. 8. *Mean* Usability and *Mean* Number of Active (in use) Sessions (in ktrip.net)

Fig. 9. Mobile-Web Service of ktrip.net with iPhone and an Android OS Phone

For Internet domain names for unified web services, we used over 300 single-character multilingual domain names including tens of multilingual (Korean) alphabet domain names as simple domain names to find information as well as to notify information in a real-time way and ubiquitously. With the test web site ktrip.net and many other TLDs (i.e. many single-character multilingual alphabet domain names), we were able to register and search mobile-web information in real-time with any mobile Internet device such as a smart phone (e.g. the iPhone and Android phone as shown in **Fig. 9**) as well as with PCs using browsers (e.g. MS Explorer 7.0+, Firefox, Safari, Opera, Chrome, etc.). With the proposed scheme for real-time estimation/analysis, we have been able to monitor/understand/compare in real-time the time-based accessibility and stochastic usability of ktrip.net and alltrip.net.

5. Conclusions

Real-time estimation and analysis of *time-based accessibility and usability* based on web interaction sessions were proposed for ubiquitous mobile-web information services. Web activity in the ubiquitous mobile-web services was presented for estimating the stochastic random variables of time-based accessibility and usability. We defined the *time-based accessibility and usability* based on session duration time and inter-arrival rate which can be estimated in real-time. We presented empirical results (http://ktrip.net/display.asp and http://alltrip.net/display.asp) based on the implementation within the global.asa program running in a web server (http://ktrip.net and http://alltrip.net). For future works, the practical applications based on the proposed *time-based accessibility and usability* in mobile-web services will be researched for real-time mobile-web advertisements for various business models based on ubiquitous mobile-web applications. We will study further the application of the stochastic usability to traffic monitoring/control as well as to the resource allocation scheme based on usability statistics for rapidly emerging mobile-web cloud computing services.

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