Fast Seamless Handoff for Mobile Cloud Computing using Service-Oriented Architecture

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Abstract: - Mobile devices are gaining in popularity and becoming the major platform for users to obtain cloud computing services at anytime and anywhere. Because of this demand, the cloud computing environment has been adapted into mobile technology by the addition of new prototypes and paradigms. From the perspective of mobile computing, the handoff process affects the Quality of Service (QoS) provisioning, reliability, and limits the mobile device's life. Thus, it is significant to handle the handoff process efficiently and intelligently when accessing the cloud computing environment using a mobile device. This paper introduces the novel service-oriented architecture to support a new handoff process. The service oriented architecture consists of five layers: application layer, IP multimedia Subsystem (IMS) layer, communication layer, Media layer, and connectivity layer.

The advantage of using service oriented architecture is that it makes it easy to access to the cloud contents and also helps in maintaining the QoS, reducing the bandwidth consumption and power consumption. This paper also introduces the fast seamless handoff for cloud computing that reduces the handover time. To validate the effectiveness of service oriented architecture for handling the different types of handoffs, we use the GreenCloud simulator that is an extension of network simulator-2 (NS2). The simulation results demonstrate that our fast seamless handoff (FSH) supported with service oriented architecture improves the data access reliability and reduces the power and bandwidth consumption. Furthermore, the performance of other well-known handoff processes is compared with our proposed FSH handoff. Based on the simulation result, our approach performs better.

Keywords: Cloud computing, fast seamless handoff, service-oriented architecture, IP multimedia Subsystem, WiMAX.

1. INTRODUCTION

Cloud computing is an emerging information technology platform that has considerably transformed the idea of computing infrastructure, software distribution, and development models [1]. Cloud computing offers attractive benefits and expedites for many organizations access to business-critical resources such as the delivery of on-demand self-services, pervasive network access, location independent resource sharing, and usage-based pricing conversion of risk. Cloud computing is projected as the next generation high-tech model for the promise of tomorrow [2], [3], [4]. Cloud computing provides numerous advantages such as ground-breaking massive paradigm where clients can distantly store confidential information in order to gain on-demand critical computing resources [2]. Furthermore, rapid deployment of mobile technology has increased the significance of cloud computing tremendously. Everyone wants to have access to cloud computing resources anytime and anywhere.

Mobile cloud computing refers to the organization where both the data processing and data storage occur externally. Mobile devices get several cloud applications from remote places to exchange successful information. Mobile cloud computing is a smart paradigm for mobile applications whereby the storage and data processing are shifted from the mobile device to authoritative and consolidated computing environment located in the clouds. Subsequently, these consolidated applications are retrieved using Wi-Fi and WiMAX based on a web browser and thin native client on the mobile devices. However, the mobile devices have a serious problem when accessing a cloud computing resource particularly during the handoff process [5].

When a mobile device accesses cloud computing resources as a handoff initiates, more power and bandwidth are consumed and QoS parameters are affected. The handling of the handoff issue has been addressed and some approaches have been proposed [6], [7], [8], [9], [10], [11], [12]. However, all these existing handoff approaches obtain cloud computing resources through the traditional way, which as a result, degrades the QoS provision.

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Maintaining the handoff in a robust way is needed in the emerging cloud computing environment [13], [14], [15]. Thus, we have introduced service oriented architecture that comprises of five layers that collectively facilitate the mobile device access cloud computing resources efficiently. Furthermore, the proposed architecture also helps in handling the fast seamless handoff. As, a result, reliable data access and delivery becomes possible. In addition, a substantial amount of power and bandwidth is saved through FHS. The remainder of the paper is organized as follows: Section-2 explains the proposed service-oriented architecture including the details of five-layers and fast seamless handoff. Section-3 presents the simulation setup and analysis of the result and final observations and conclusions are presented in Section-4.

2. PROPOSED SERVICE-ORIENTED ARCHITECTURE OF FAST SEAMLESS HANDOFF

The handoff process in the cloud computing is very challenging [14]. We deploy service oriented architecture depicted in Figure 1 with several utilities to help in the fast handoff process. Our service oriented architecture consists of five layers, which support the fast handoff process using WiMAX service.

- Application layer
- IP Multimedia Subsystem (IMS) layer
- Communication layer
- Media layer
- Connectivity layer

2.1. Application Layer

This layer involves the home subscriber server (HSS) that coordinates with the cloud computing environment. It performs as master database to support the IMS layer. Once HSS provides the support to IMS, then IMS is enabled to handle the calls effectively. The HSS comprises of the subscription-related information (SRI). In the SRI, the profiles of subscribers are stored. Thus, prior to giving the access to the user, the authentication and authorization processes are conducted to the users. HSS also provides the IP information and subscriber's location. The working process of HSS is similar to *Global System for Mobile (GSM) home location register (HLR) and authentication center.*

2.2. IP Multimedia Subsystem (IMS) layer

This layer involves the integrated network telecommunication carrier's concept that enables the use of internet protocol (IP) to initiate the packet communication over a wireless network. This layer provides the supports for different types of services such as web, internet, fax, email, telephony, videoconference, video-on-demand, and voice over IP service. IMS uses the registration process to obtain the location information of mobile node. The IMS comprises of call session control function (CSCF) that is initially used for creating the binding between IP address of mobile device and public user identity. The CSCF is classified into the following sub-classes:

- Serving-CSCF (S-CSCF)
- Proxy-CSCF (P-CSCF)
- Interrogating-CSCF (I-CSCF)

2.2.1. Serving- CSCF

The central node performs session control and is located in the home network. S-CSCF maintains the registration status of the users as well as the timer. It provides two important features. First, it interfaces to download the user's profiles and creates the association. Second, it sits on the trail of signaling messages for the locally registered users and also monitors the every message. S-CSCF takes the decision regarding the transfer of the applications to the SIP messages in order to provide the services. Furthermore, S-CSCF performs the job of routing as well as administrating the policy of network operator.

2.2.2. Proxy-CSCF

It is SIP proxy that is the first point to be used for interacting with the IMS terminal. P-CSCF is set either in the visited network or in the home network. The P-CSCF uses a specialized session border controller (SBC) for the user network interface. Therefore, this SBC feature helps protect the network and IMS terminal. IMS terminal determines its P-CSCF using either dynamic host configuration protocol (DHCP) or IMS management object. P-CSCF is allocated to the IMS terminal prior to registration process and is not changed during the registration process. It helps inspect the signal and ignores the unencrypted signaling. Furthermore, P-CSCF contains the policy decision function (PDF) that authorizes the quality of service (QoS) of media plane resources. The use of PDF helps manage the bandwidth utilization.

2.2.3. Interrogating-CSCF

It is part of administrative domain that does the job as another SIP function. The IP address of the I-CSCF is distributed to the domain name system (DNS). If the domain uses the service record (SRV record) and name authority pointer (NAPTR) for determining the remote servers, then the registration process for SIP packets is possible. SRV records are to specify the data in a DNS that defines the location of the hostname and port number of the particular services when mobile attempting to handoff process. The NAPTR is the resource record in DNS of the Internet. The Internet telephone requires the NAPTR records for mapping the user addresses and servers in SIP. I-CSCF forwards the SIP request to the S-CSCF to refresh the exiting registration process and also informs the network regarding changed situation of mobile node. Subsequently, the mobile phone initiates the re-registration process.

2.3. Communication Layer

This layer routes the data and coordinates with IMS and media layer. It involves the breakout gateway control function (BGCF), the media gateway controller function (MGCF) and the media resource function controller (MRFC). The BGCF is the SIP proxy that processes a request to route the data from S-CSCF when S-CSCF identifies that a session cannot be transmitted using a domain name server (DNS). Furthermore, BGCF includes the routing features based on telephony records. The MGCF is considered as SIP endpoint that handles the call exchange between SIP and bearer-independent call control (BICC). The MRFC is the signaling node that deduces information impending from an application server (AS) and S-CSCF to handle the MRFP.

2.4. Media Layer

This layer offers the media related functionalities such as management of the voice streams and playing of tones including fast handoff process. The media layer involves the media resource function controller (MRFC) and a media resource broker (MRB). The MRFC works as media plane node to process and mix the media streams. It also has a capability to handle the shared resources. The MRB is responsible for collecting a proper available media resource function (MRF) information and delivering of suitable MRF information to overriding objects such as the AS. MRB involves the query mode and In-line mode. In the query mode, MRB sets up the call by getting the response of MRF and in-line mode, MRB send the SIP invite to MRB. Furthermore, the handoff process is managed in this layer. The MRFC and MRB interconnect with IPv6 to ensure the handoff process. Thus, we deploy fast seamless handoff process to improve the mobile cloud service because of the change in its point of connection.

2.4.1. Fast seamless handoff process

The mobile nodes (MNs) move quickly from their corresponding home domains or communicator nodes yield significant binding update (BU) signaling traffic. As a result, the mobile nodes suffer because of handoff latency and packet loss when no Mobile IP protocol is used to handle this critical situation. By handling this critical situation particularly accessing the cloud environment, we introduce fast seamless handoff Mobile IPv6 (FSHIPv6) that provides the localized mobility management. This protocol aims is to lessen the signaling load because of node mobility. FSHIPv6 involves the mobility management features inside the local domain controlled by a mobility anchor point (MAP). Our architect focuses on reducing the signaling load within intra domain (same domain) in case of handoff. This results to improve handoff performance by dipping packet loss and handoff latency. Once MNs are in the handoff process, the re-registration process in required. Re-registration is activated by two states:

First, the Periodic Re-Registration (PRR) that periodically informs the “active” state of MNs to the home network for eluding the termination of the set registration timer between MNs and home network. Second, Re-Registration for Change Capabilities (CCRR) is originated when the MNs change its capabilities. Particularly in the second condition, the MNs moves and joins to another entry point of the network. Thus, the registration process is initiated. The objective of PRR is to determine if the MNs are still registered with the home network. In this situation, home network starts the de-registration process because a registration timer is timeout. The objective of CCRR informs the change of location of MNs to the network.

The former is activated periodically by the timer and the latter is used when changing the parameters. Both the CCRR and PRR procedures require to refresh the registration timer of the users so that MNs should be enabled to start new session. In our proposed fast handoff process, IMS layer helps identify the MN’s current registration status that is completely different from traditional network. Thus, the smart phone in the mobile cloud environment is guaranteed to access the Internet services including other features such as social network, instant messaging, weather update, online gaming, Internet TV, remote web applications and document processing. The activities of retrieving the cloud services also specify that the registration status of MNs. Therefore, IMS during the session establishment helps refresh the registration timer when accessing the cloud that can reduce the PRR times. As a result, MNs are enabled to save the time caused by whatever can save the power of the mobile periodic re-registration. The fast handoff process is explained in algorithm 1.

Algorithm 1: Fast Handover process in cloud computing environment

1. Variable Initialization (IO_t : Incoming and Outgoing traffic, R_s: Session Request, R_t: Registration timer, IP_{MIS} : IP multimedia system, φp: Cloud service monitor, β: Saving call session control function, γ: Proxy call session control function, M_{id}: Mobile ID, M_n: Mobile node, L_{reg}: Intra region, ΔB_{s1}: Base station, ΔB_{sn} : Base station N, τ: Change Capabilities for Re-registration)
2. **Input :{**R_{rp}: Received response, $N_{handoff}$: Node handoff process)
3. **Output:** ($\Delta\omega$: Service response, A_{cs}: Access for cloud service, P_m: Publish message, ε: Event , R_τ: Re-registration request)
4. **Set** M_n is initially connected with ΔB_{s1} in L_{reg}
5. **if** $N_{handoff}$ ofM_n from ΔB_{s1} to ΔB_{sn} within L_{reg} then
6. **Initialize** IO_t for registration during the $N_{handoff}$
7. **end if**
8. **if** IP_{MIS} receives the R_s from M_n then
9. **Set** $IP_{MIS} \rightarrow R_t$ // IMS reset registration timer
10. **end if**
11. **if** $M_n \forall \in R_{rp} \rightarrow IP_{MIS}$ then // if mobile node receives the response from IMS
12. **Set** $M_n \rightarrow R_t$// Mobile node reset the registration timer
13. **end if**
14. **if** εoccurs for A_{cs} then
15. **Display** $P_m \rightarrow \beta$&&γ // Cloud service Monitor display publish message to P-CSCF and S-CSCF

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16. **Set** $R_t \rightarrow \Delta\omega$ using φp / Cloud service monitor incorporates the timer in service response
17. **end if**
18. **if** β receives $P_m \in \varphi p$ && M_{id} then // IF "CLOUD SERVIC MONITOR" receives the publish message from S-CSCF
19. **compute** M_{id} using β // Compute mobile ID using S-CSCF
20. **Set** R_t // IMS reset registration timer
21. **end if**
22. **if** M_n receives $\Delta\omega \propto R_t$: then // Mobile node receives the service response including timer
23. **Set** $M_n \vdash R_t$ // Mobile node rests the registration timer
24. **end if**
25. **if** $\tau \in \varepsilon$ then // if Change Capabilities for Re-registration event occurs
26. **Initiate** $M_n \leftarrow R_r$ // Set re-registration request
27. **If** IP_{MIS} receives R_r then // IMS receives registration request
28. **Set** $IP_{MIS} \rightarrow R_t$ //IMS reset registration timer
29. **end if**
30. **if** M_n receives R_{rp} then // Mobile node receives the response
31. **Set** $M_n \rightarrow R_t$ // MN resets the registration timer
32. **end if**
33. **end if**
34. **If** $R_t = 0$ // If registeration timer is zero then Periodic Re-Registration occurs
35. **Initiate** $M_n \rightarrow R_r$ // MN initiates the re-registration
36. **If** IP_{MIS} receives R_r then// IMS receives the re-registration request
37. **Set** $IP_{MIS} \rightarrow R_t$ // IMS reset registration timer
38. **end if**
39. **if** M_n receives R_{rp} then // MN receives response
40. **Set** $M_n \rightarrow R_t$ // MN resets the registration timer
41. **end if**
42. **end if**

In line-1, the variable initialization process is initiated that involves the incoming and outgoing traffic, session request, registration timer, IP multimedia system, cloud service monitor, saving call session control function, proxy

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call session control function, Mobile ID, mobile node, intra region, base station, and change capabilities for re-registration. In line-2, Input variables are explained including received response, and node handoff process. In line-3, output variables are described including Service response, access for cloud service, publish message, event, and re-registration request. In line-4, the mobile node is shown connected with base station in intra region. In lines-5-6, a node intents and initiates the handoff process from one base station to another base station within the intra region. In line-8, IP multimedia system receives the session request from the mobile node. In line-9, once multimedia system receives the session request then it resets the registration timer. From lines 11-12, when mobile node receives the response from IMS; then it resets the registration timer. From lines 14-16, events occurring process is shown for getting the access for the cloud service. Based on the event, the cloud service monitor displays and publishes the messages to [P-CSCF] and [S-CSCF]. Subsequently, the cloud service monitor incorporates the timer in the service response.

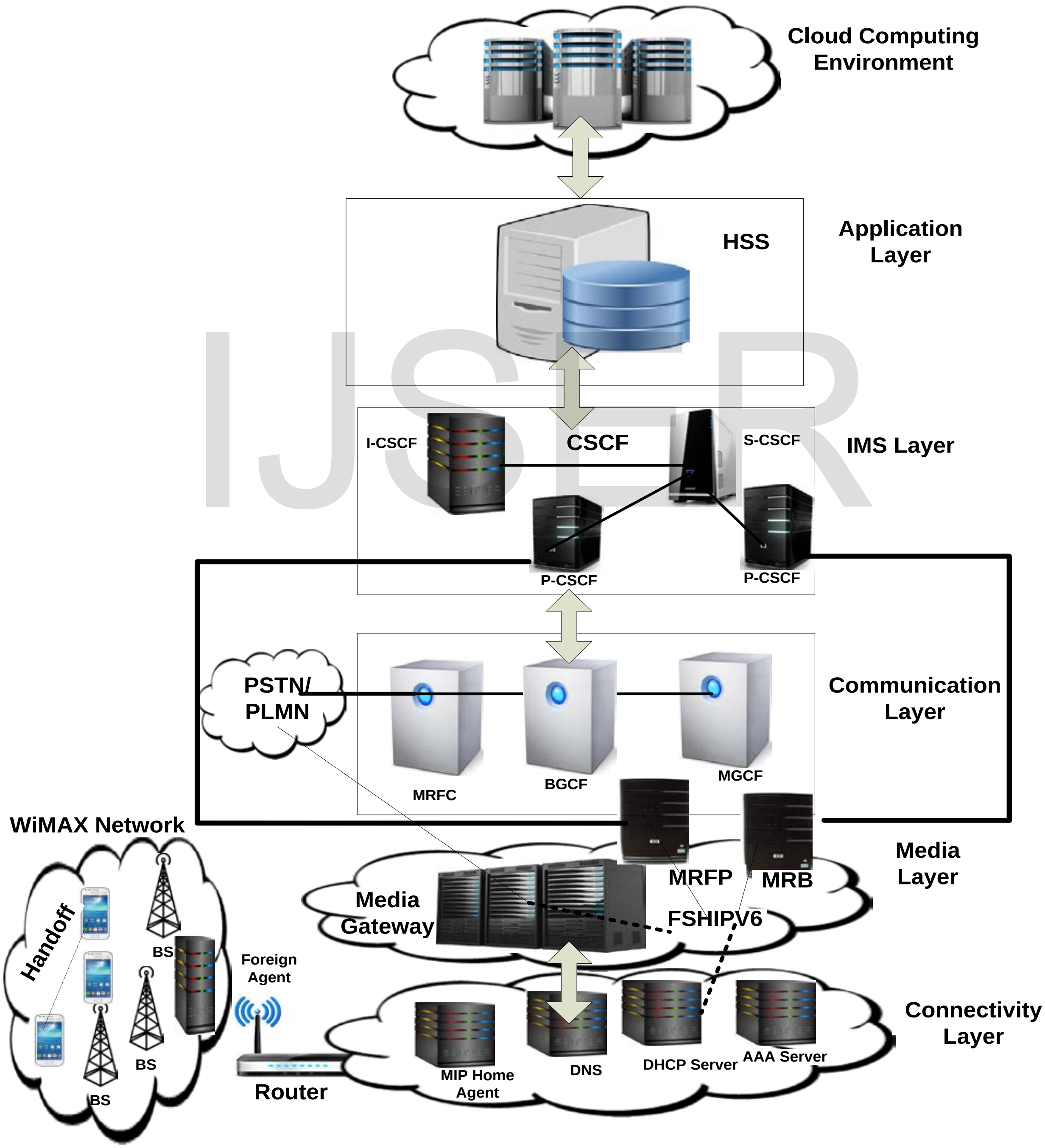

Figure 1: Service-oriented architecture to support handoff processes

From lines 18-20, If the cloud service monitor receives the publish message from [S-CSCF]; then it computes the mobile ID using [S-CSCF]. Later on, IMS resets the registration timer. From lines 22-23, the mobile node receives the service response including the timer then it rests the registration timer. From lines 25-28, it is shown that if change capabilities for re-registration event occur; then mobile node sets the re-registration request. When IMS receives registration request; then it resets registration timer. After resetting the time, the mobile node receives the response and it also resets the registration timer shown from lines 30-31. From lines 34-37, it is shown if the mobile node's registration timer is set zero; then a periodic re-registration request occurs, and a mobile node again initiates the re-registration process. Once the IMS receives the re-registration request; then IMS again resets the registration timer. Finally, mobile node receives the response, and it resets the registration timer explained in the lines 39-40.

1.1. Connectivity layer

This layer interacts with media layer to provide the services such as determining the domain using domain name server (DNS). The authentication, authorization, and accounting (AAA) server is used to handle the requests to access the cloud resources. AAA server particularly interrelates with gateway servers and network access using directories and databases. The connectivity layer involves the dynamic host confirmation protocol (DHCP) to resolve the issuance of IP address. Furthermore, the mobile IP agent is also part of this layer that helps in handling the handoff process. When MNs initiate the handoff process within intra location, then MNs do not need to change the base station and do seamless handoff that helps reduce the handoff timing and improve the QoS.

2. SIMULATION SETUP AND ANALYSIS OF RESULTS

We analyze the performance of the proposed fast seamless handoff and compared it with well-known designed hand off processes for the cloud computing; vertical handoff algorithm (VHA) [16], handoff-as-a-service (HaaS) [17] and Optimized fast handover (OFH) [18]. The proposed model is programmed in C++ and confirmed on the GreenCloud simulator that is the extension of network simulator-2 (NS2). We used merging process to install both NS2 and GreenCloud. The Ubuntu 13.0, a supporting operating system, is used. The experiments are run on the machine with 3.0 GHz Dual Core CUP with 4 GB RAM. The size of the network consists of 400X400 Square meters and maximum number of 90 mobile subscribers were used. Each link has 4 MB/Sec bandwidth with 350 Kilobytes/Sec. The GreenCloud demonstrates the repeatable and manageable environment that shows the realistic behavior. The proposed fast seamless handoff was tested in different scenarios to determine its strength. Based on the simulation, we are interested in the following features.

- Bandwidth Utilization
- Power Consumption
- Reliable Data Access
- Service Level Availability.

2.1. Bandwidth Utilization

In the first scenario, we examine the bandwidth utilization of the FSH, VHS, OFH and HaaS in the cloud computing environment. Success of our proposed FSH is demonstrated in the obtained results which are comparatively similar to the realistic environment. Based on the simulation results, we observe that FSH uses minimum power consumption as compared to other competing handoff approaches depicted in Figure 2. In the results, we notice that when the number of the mobile subscribers increases the bandwidth consumption also increases. So, the bandwidth consumption is directly proportional with the number of mobile subscribers. FSH consumes 48.5% bandwidth of the entire allocated bandwidth, whereas the other competing approaches use the 66.2% to 76.1% bandwidth utilization. The reason for the performance degradation of the other approaches is the longer registration process and lack of the localized mobility management features. As a result, other approaches consume more bandwidth utilization during the handoff process.

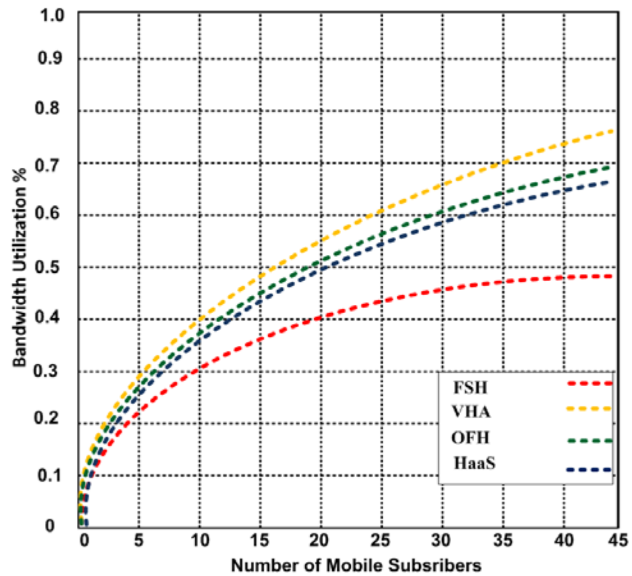

Figure 2: Bandwidth Utilization of proposed FSH and other handoff schemes

2.2. Power Consumption

The power consumption is one of the critical parameters on which the performance and lifetime of the network and efficiency of mobile subscriber depend. In Figure 3, we show the power consumption of FSH and other competing handoff processes. Based on the simulation results, we observed that power consumption also increased as the number of mobile subscribers increased. FSH overall consumes less power as compared with VHA, OFH, and HaaS handoff. However, our approach has minor limitations; when few mobile subscriber initiate the handoff process then our approach behaves like other handoff approaches. Therefore, our approach is designed to support the maximum number of mobile subscribers. FSH consumes the power 52.9% of overall available power, whereas,other approaches consume the power from 58.2% to 64.6%. The results confirm that FSH is minimum power consumption approach so that mobile subscriber can stay alive for longer time.

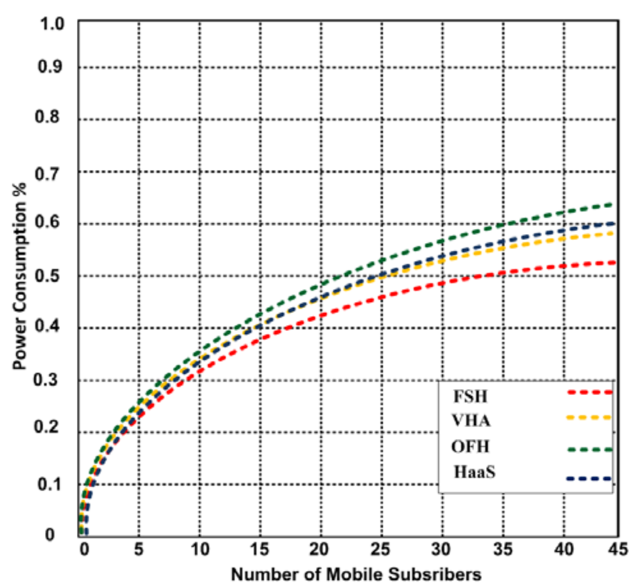

Figure 3: Power Consumption of proposed FSH and other handoff schemes

2.3. Reliable Data Access

When a mobile subscriber initiates the handoff process, then reliable data delivery is of paramount significance because there is abundant chance of losing the data once handoff is instigated. In Figure 4, we show the reliable data delivery of FSH and other competing handoff process approaches. Based on the simulation, we observed that FSH has almost stable data delivery that is almost between 95-96% throughout the simulation time. However, other approaches reduce the data delivery, which show from 95% to 75%. We also noticed that when the number of subscribers increases other approaches affect the data delivery. Hence, we proved that other approaches are not competent as the number of mobile subscribers increases.

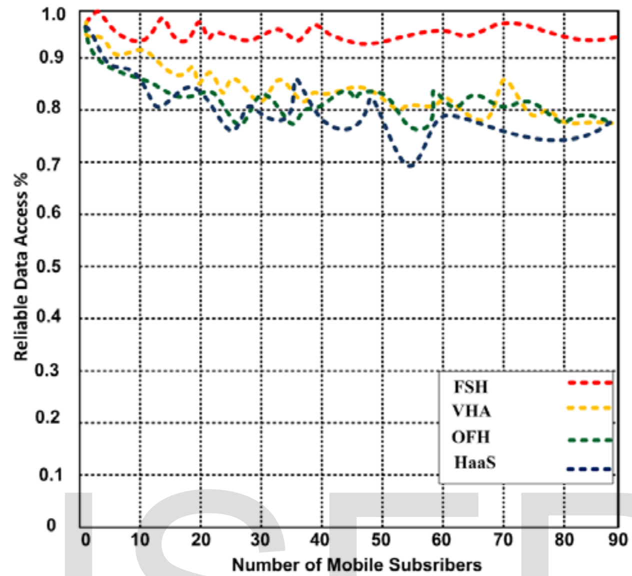

Figure 4: Reliable data access of proposed FSH and other handoff schemes

2.4. Service Level Availability

This feature shows the productivity of our approach and other competing approaches. This confirms how much cloud services can be achieved through handoff process using mobile phones. In Figure 5, we observed that FSH maintained better service availability as compared with other handoff approaches.

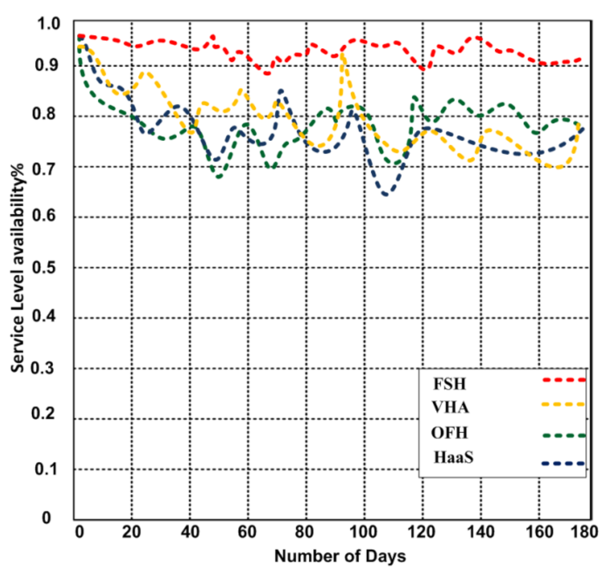

Figure 5: Service availability of proposed FSH and other handoff schemes

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Because, FSH has a service level availability 94.6-90.2% during the period of 180 days that is not too much fluctuation in service. However, other approaches reduce the service availability from 94.3-70.1%. Based on the result, we confirm that FSH outperforms to other approaches.

3. CONCLUSION

The fast seamless handoff for mobile cloud computing has been introduced in this paper. The seamless handoff is supported using service oriented architecture over WiMAX. The service oriented architecture is robust and highly supported for different types of handoff particularly fast seamless handoff. The service oriented architecture consists of five layers: application layer, IP multimedia Subsystem (IMS) layer, communication layer, media layer, and connectivity layer. The advantage of using five layering approach helps reduce the power consumption, bandwidth. In addition, it also improves reliable data access and service level reliability.

The handoff-supporting service oriented architecture is simulated using the GreenCloud. Based on the simulation result, we have proved that our proposed approach FSH reduced 27.6- 17.7% and 5.3-11.7% bandwidth and power consumption respectively. In addition, FSH improved the 10% and 10.2% reliable data access and service level reliability. The results confirm that our service oriented architecture is promising paradigm forgetting the cloud computing resources during handoff approach. In the future, we will investigate other several parameters such as QoS, scalability and reliability. .

REFERENCES

[1] Yuan, Hang, C-CJ Kuo, and Ishfaq Ahmad. "Energy efficiency in data centers and cloud-based multimedia services: An overview and future directions." In Green Computing Conference, 2010 International, pp. 375-382. IEEE, 2010.

[2] Choi, Min, Jonghyuk Park, and Young-SikJeong. "Mobile cloud computing framework for a pervasive and ubiquitous environment." *The Journal of Supercomputing* 64, no. 2 (2013): 331-356.

[3] Simoens, Pieter, Filip De Turck, Bart Dhoedt, and Piet Demeester. "Remote display solutions for mobile cloud computing." *IEEE Internet Computing* 13, no. 5 (2009).

[4] Shiraz, Muhammad, Abdullah Gani, Rashid HafeezKhokhar, and RajkumarBuyya. "A review on distributed application processing frameworks in smart mobile devices for mobile cloud computing." *Communications Surveys & Tutorials, IEEE* 15, no. 3 (2013): 1294-1313.

[5] Hani, QassimBani,and Julius Dichter "Handover Time Delay Reduction and Its Effects in Cloud Computing." *Communications and Network* 6, no. 04 (2014): 243.

[6] Ryu, Seonggeun, Kyunghye Lee, and YoungsongMun. "Optimized fast handover scheme in Mobile IPv6 networks to support mobile users for cloud computing." *The Journal of Supercomputing* 59, no. 2 (2012): 658-675.

[7] Lee, DaeWon, HwaMin Lee, DooSoon Park, and Young-SikJeong. "Proxy based seamless connection management method in mobile cloud computing." *Cluster computing* 16, no. 4 (2013): 733-744.

[8] Ferretti, Stefano, Vittorio Ghini, Fabio Panzieri, and Elisa Turrini. "Seamless support of multimedia distributed applications through a cloud." In *Cloud Computing (CLOUD), 2010 IEEE 3rd International Conference on*, pp. 548-549. IEEE, 2010.

[9] Sardis, Fragkiskos, Glenford E. Mapp, Jonathan Loo, Mahdi Aiash, and Alexey Vinel. "On the investigation of cloud-based mobile media environments with service-populating and QoS-aware mechanisms." *IEEE transactions on multimedia* (2013).

[10] Chen, Yuh-Shyan, and Kun-Lin Wu. "A cross-layer partner-assisted handoff scheme for hierarchical mobile IPv6 in IEEE 802.16 e systems." *Wireless Communications and Mobile Computing* 11, no. 4 (2011): 522-541.

[11] Chiu, Kuan-Lin, Yuh-Shyan Chen, and Ren-Hung Hwang. "Seamless session mobility scheme in heterogeneous wireless networks." *International Journal of Communication Systems* 24, no. 6 (2011): 789-809.

[12] Zhu, Kun, DusitNiyato, Ping Wang, Ekram Hossain, and Dong In Kim. "Mobility and handoff management in vehicular networks: a survey." *Wireless communications and mobile computing* 11, no. 4 (2011): 459-476.

[13] Huerta-Canepa, Gonzalo, and Dongman Lee. "A virtual cloud computing provider for mobile devices." In *Proceedings of the 1st ACM Workshop on Mobile Cloud Computing & Services: Social Networks and Beyond*, p. 6. ACM, 2010.

[14] Yang, Zhen, Xing Liu, Zhongwei Hu, and Chaowei Yuan. "Seamless Service Handoff Based on Delaunay Triangulation for Mobile Cloud Computing." *Wireless Personal Communications* (2014): 1-15.

[15] Bellavista, Paolo, Giuseppe Carella, Luca Foschini, Thomas Magedanz, Florian Schreiner, and Konrad Campowsky. "QoS-aware elastic cloud brokering for IMS infrastructures." In *Computers and Communications (ISCC), 2012 IEEE Symposium on*, pp. 000157-000160. IEEE, 2012.

[16] Ravi, Anuradha, and Sateesh K. Peddoju. "Handoff Strategy for Improving Energy Efficiency and Cloud Service Availability for Mobile Devices." *Wireless Personal Communications* (2014): 1-32.

[17] Xu, Ke, Ryan Izard, Fan Yang, Kuang-Ching Wang, and Jim Martin. "Cloud-based handoff as a service for heterogeneous vehicular networks with open flow." In *Research and Educational Experiment Workshop (GREE), 2013 Second GENI*, pp. 45-49. IEEE, 2013.

[18] Ryu, Seonggeun, Kyunghye Lee, and YoungsongMun. "Optimized fast handover scheme in Mobile IPv6 networks to support mobile users for cloud computing." *The Journal of Supercomputing* 59, no. 2 (2012): 658-675.