Exploring User's Habits and Virtual Communities to Improve IP-Connectivity Management

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***Abstract*— A wireless connectivity island is a geographic area covered by a particular wireless ISP. Nowadays, mobile users possessing multi-homing mobile devices can have IP-connectivity almost everywhere, while being on the move. In terms of vertical handover, these users jump from a connectivity island to another that could differ by communication technology, access provider, QoS conditions and price. The mechanisms for vertical handover rely on broadcasted information or on QoS status of the wireless environment to comply with the applications requirements and user's preferences. In this paper, we propose a complementary approach to improve the accuracy and handiness of the network information typically used in the vertical handover solutions. Since the mobile users are not always on the move, we try to identify certain user states in a context-aware manner and trigger appropriated connectivity management tasks. While the user is on the move, we retrieve and store user's connectivity experiences through a route, aggregating time and location to represent a habit. Theses experiences are shared as feedback in virtual communities in order to reach potentially interested people who share similar movements. Moreover, we describe the key points of the implementation of a prototype called Wireless Footprinting and discuss some quantitative experiments in a testbed with mobile IPv6.**

***Index Terms*— Context-aware systems, Mobile computing, IP-connectivity management**

I. Introduction

In the mobile computing area, a significant amount of research has been conducted to decide the most suitable network for a mobile user. Such decision making is aimed at fulfilling user's QoS requirements and save resources (e.g. battery power) and perform a vertical handover to a different network when necessary or convenient. Some of the proposed solutions in this area predict network QoS conditions in a near future, and use a set of parameters, e.g. user's preferences and QoS demanded by applications, in order to improve the handover decision making [1, 2, 3, and 4]. These works provided solutions to keep the device connected on the move, although, mobile users are not always on the move. Firstly. it is possible that these users are at home or work place with low mobility, unlimited power supply, and using a WLAN connection with high QoS. Secondly, these users could also be at an unknown place, without IP-connectivity, with limited power supply, either moving or stationary. The most researched mobile user state in the literature is the third state when they are moving in connectivity islands with unknown or predicted QoS, and relying in a battery. We consider that a wireless connectivity island is a geographic area covered by a particular wireless Internet Service Provider (ISP). We believe that these three states can be possibly identified in a context-aware manner [5 and 6], and explored to help the IP-connectivity management. The key idea herewith is to define management tasks which will be triggered when the device is in a specific state.

While moving, the user cannot rely on a single wireless network, but must also exploit a wide variety of connectivity options [1]. Developing standards in order to provide seamless roaming between heterogeneous networks is a main challenge being addressed by the IEEE 802.21 [7] expert group. This group has developed a Media Independent Handover (MIH) architecture that uses services to deal with events, to execute commands, and to share information between network's layers.

We were motivated by the capabilities aimed at by the IEEE 802.21 effort that will allow a handover decision to be made cooperatively. Our hypothesis is that a mobile user's habits and social relations can be mapped and used to improve the accuracy of the wireless QoS data frequently used by solutions proposed in the area of vertical handover. A user's connectivity experience on a particular route can be combined with time and location in a context-aware manner to define a habit. The connectivity path through this route is composed of a set of access points being used by the mobile user. This information can be stored and shared as feedback in virtual communities to reach potential

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interested people with similar habits (e.g. a group of co-workers may share certain common habits).

This paper describes a simple way to explore user's habits and virtual social communities to aid the IP-connectivity management tasks. In particular, we see the following three major contributions:

i) We elaborate the idea of context-aware and feedback-based wireless IP-connectivity management.
ii) We illustrate on sharing connectivity experience, through a route, using virtual communities.
iii) We present a prototype called Wireless Footprinting and initial test results in a testbed with mobile IPv6 in order to validate the main ideas.

The remainder of this paper is organized as follows: Section II describes the proposed context-aware and feedback-based mechanism. Section III discusses main implementations points of a prototype called Wireless Footprinting. Section IV presents initial test results in a mobile IPv6 testbed. Finally, Section VI concludes our finding and provides future work areas.

II. Context-aware and Feedback-based Mechanism

Our proposed approach for IP connectivity management aims at improving a terminal controlled handover in the 802.21 MIH environments. In order to achieve this we propose a set of services at the network application layer that interact with feedback services and virtual social networks via the Internet connection. The Figure 1 shows these three entities and the main services that compose our solution.

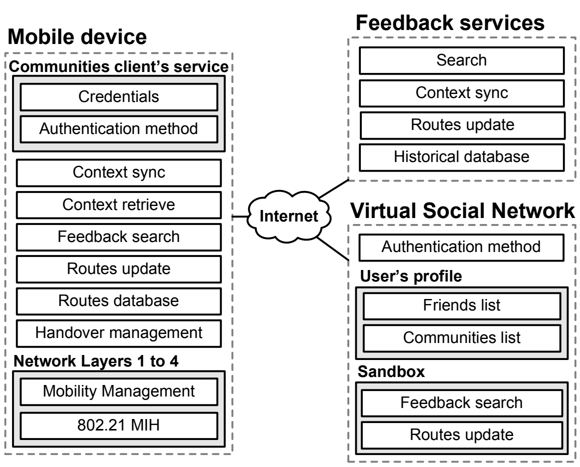

Figure 1. Entities used to share feedbacks through virtual communities

For instance, feedback services are similar to wireless access point databases such as Place Lab [9] and Sentient Van [10]. We extended these kinds of services to synchronize and search network context data in a route using virtual communities, as detailed in the sub-section II.B and II.C. Generally, virtual social networks are web applications based on certain standards that provide an API (Application Programming Interface) and a sandbox (application directory) for the third party application development and deployment, respectively. The rest of this section describes in details how these entities interact to help the IP connectivity management.

A. User states related to IP-connectivity management

Mobile users are not roaming around the whole time. They have habits that can be identified in a context-aware manner and identifying these habits could be useful for the IP connectivity management. The user can be moving in a wireless network, with unknown or predicted QoS, and with finite power supply (e.g. battery); let this be state **A**. At another time, state **B**, the user could be stationary, with good QoS conditions and with power supply available. Furthermore, the user could be stationary or moving in a unknown or blind connectivity island, without IP-connectivity, and with good or limited power supply; let this be state **C**. These states are compiled in Table 1. In this table, we highlight these states, the conditions that characterize each one, and the tasks that can be done at the respective state.

Table 1. User's states in terms of IP-connectivity

State	Conditions	Tasks
A	- Moving - predicted or unknown QoS - limited power supply	- sense context changes - store context data - handover decision making
B	- stationary or low mobility - good QoS - good power supply	- update feedback data - upload experience data
C	- stationary or moving - without IP-connectivity - with or without power supply	- ask for somebody - use an opportunistic connection

These states can be identified using context information, and certain actions are triggered based on the user's state. The state **A** is widely studied and a user's mobile device senses the wireless environments, makes some tests at the current network (e.g. estimate the throughput available), stores context data, and chooses the next access point on move. At the state **B**, a user's mobile device uploads its connectivity experiences, share this information in a virtual community, and retrieve feedbacks from other users. The key idea herewith is to provide services to update the mobile user's information about a connectivity path, which could be compared to sharing weather information or traffic conditions in a particular area among a group of interested people. Finally, at the state **C** the users can ask for connectivity information just as they would ask about the weather or traffic conditions at an unknown place or ask for content using an opportunistic connection [8].

B. On the move

It is beneficial for the users equipped with multi-homing mobile devices to choose the next access point when they are jumping from a connectivity island to another. The flowchart in the Figure 2 shows a set of actions to be taken while the user is on the move. In order to be always connected, a mobile device should continue sensing context changes. In case of the network context change, the current context is retrieved and a request for feedbacks in the same place is sent (this information was updated when the user was at state **B**). If there are no feedbacks received, the system chooses de AP using QoS parameters, like work done in [4]. If there is a feedback, the system verifies if it is a known habit (route). The present work aims to show the details of the last case, where the users is going through a known route.

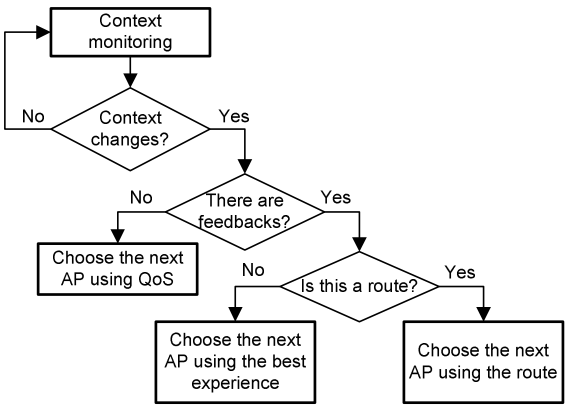

Figure 2. Flowchart summarizing the actions on move

In the context of this paper, a route is a set of geo-referred points where the user retrieved network context data, as is shown in Figure 3. In this figure, there is a hypothetical route where a mobile user traverses through in the morning (between 07:00 and 07:55 a.m) and in the evening (between 05:05 and 06:00 p.m). The five nodes represent the critical places where the user jumps from a connectivity island to another and stores context data.

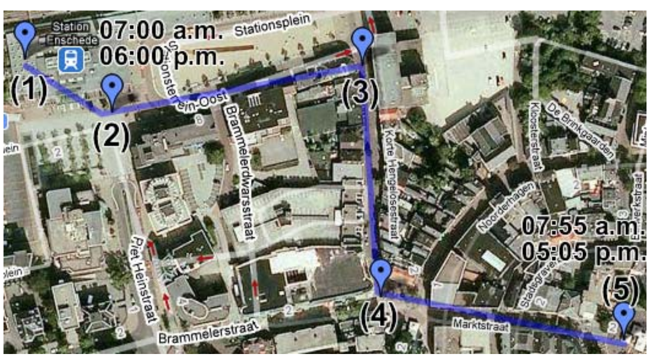

Figure 3. A hypotetical route with five critical points

The route and the networks available in each point can be represented as a graph similar to the one in Figure 4. At node (1) there are two networks "a" and "b" (edges), and the user is connected in "a". Then, at node (2) there are three networks "a", "b" and "c", and the user exchange network from "a" to "b". At the end (node 5) the user went through networks "a", "b", "c" and "d", respectively. This set of networks composes the connectivity path in the route; we also call it as connectivity experience in a route. We believe that this information can be shared and improved in a collaborative way in virtual communities, as describe in the next sub-section C.

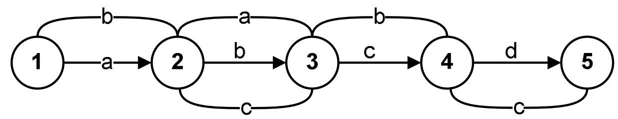

Figure 4. Abstract representation of a route

We may have some context data related to each network visible in a node, as presented in Table 2. In this case, the context data is: network name, usage of the access point, signal quality of the network and cost per Mbytes. The usage is the representation of times that a mobile user chooses the specific network in this route. Such usage can be retrieved from a historical database. With this data and the graph representation, we use sort-path algorithms to retrieve the connectivity path most used, with the best signal quality or with the lower cost. Also, we can use most sophisticate techniques of data mining, as in [5 and 6].

Table 2. Contextual data related to each network available in a route

Node	Network context data			
	Network	Usage (%)	Signal (%)	Price ($/MB)
1	A	60	70	00.00
	B	40	80	10.00
2	A	20	60	00.00
	B	50	90	10.00
	C	30	50	10.00
3	B	45	70	10.00
	C	55	60	10.00
4	C	70	40	10.00
	D	30	65	10.00
5	C	70	30	10.00
	D	30	90	10.00

Summarizing above, the steps of our solution are shown in the Figure 5. In this figure, at the first moment $\mathbf{i_0}$ (1), the mobile user starts walking, so the device senses the context changes using a GPS system $\mathbf{i_1}$ (2). In the next step (3), the user is near to the edge of the current wireless network **A**, so the network context data is retrieves and locally stored; in addition the mobile device requests previous feedbacks updates. Finally, at instant $\mathbf{i_3}$ the mobile users have the feedback of the whole route.

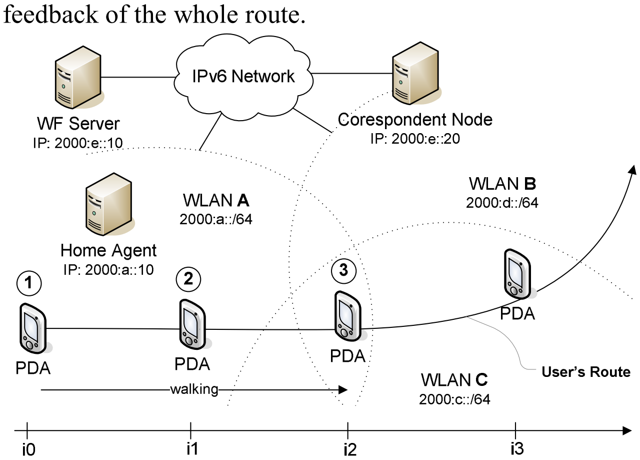

Figure 5. Steps of the context-aware and feedback-based mechanism in a tipical NGN environment, that also is a testbed IPv6 with mobile IP

C. *Sharing and updating feedback*

We believe that the connectivity experiences can be shared, updated and improved as a social media. People that share some common places can collaborate to improve their on-line experiences at those particular places. The collaboration can be comments, rates and sampling. We are developing tools to make it possible. Right now, we know how to share these experiences in a social environment.

The Figure 6 illustrates the interactions between the entities shown in Figure 1 to update feedback data about a known mobile user's route. The interaction is initiated by the mobile device making the authentication on the virtual social network; it will provide access to his communities, friends, and the application embedded at the user's profile. Next step, call the method *routeUpdate* that receives as input parameters, the community and the information about the route (e.g. ser of geographical coordinates or an alias). The application running in the sandbox searches for feedbacks of users in the same community that has experiences in the same route. Once the data is up to date the device does log off to close the session.

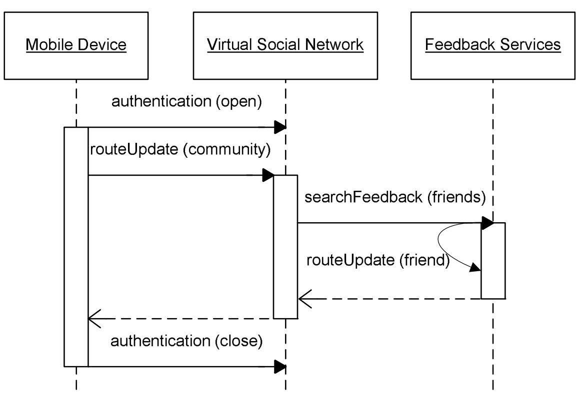

Figure 6. Sequence diagram of a user updating feedback data using a virtual community

III. IMPLEMENTATION DETAILS

The idea of sharing IP connectivity experience is implemented in a tool called Wireless Footprinting (WF) which is a WF knowledge-based technique to inform about network availability at a particular point before the mobile device reaches that point. The WF tool has two modules: WF Server and WF Client. The first one is responsible to store user's network context data and provides a feedback search service. The second one is able to retrieve and store network context data, synchronize this data with the server, search for feedbacks of other users in the server and make the handover decision. The tool runs in the background monitoring context changes when the mobile user is roaming.

We are currently developing a prototype using Java Standard Edition platform in Linux powered devices. The mains functional requirements that we've implemented in WF prototype are the following:

Context monitoring: The network context changes are closely related to user's movements. So, this functionality was implemented using a GPS device and WF Client is constantly observing the geographical coordinates changes. For this, we use a service daemon called ***gpsd*** that monitors and queries GPS devices providing location and velocity information at a mobile device.

Retrieve and store network context data: The most recent version of the WF prototype obtains data only about Wi-Fi networks in the environment. We've been using the ***wireless-tools***, available in almost all Linux distributions, to get network ssid, mac address, channel, signal quality, signal level and noise level.

Feedback search: Given geographical coordinates of user's current location the service returns the past experience (feedback) of the user or other users at the same place. If the user is going through a known route the service returns a XML file as shown in the Figure 7. In this figure we have an instance of the file used to exchange route data between WF Client and Server.

```
<route>
 <time>
  <interval begin="07:30 a.m." end="07:55 a.m"/>
  <interval begin="06:00 p.m." end="06:25 p.m"/>
 </time>
 <points>
  <point>
   <latitude>-22.977666</latitude>
   <longitude>-43.188828</longitude>
   <mac>00:0E:2E:BF:E3:DE</mac>
   <network>"WLAN A"</network>
   <standard>802.11g</standard>
   <quality>83</quality>
   <channel>6</channel>
   <signalLevel>-51</signalLevel>
   <noiseLevel>-85</noiseLevel>
   <batery>100</batery>
   <ip>192.168.0.1</ip>
   <netmask>255.255.255.0</netmask>
   <gateway>192.168.0.1</gateway>
   <dns>143.107.231.12</dns>
  </point>
  <!-- Others points in the same route -->
 </points>
</route>
```

Figure 7. XML file used in feedback search service

Handover management: This module decides what is the next access point using current network context data and past experience in the same place. If there is no experience the decision is made using QoS parameter similar to that in [4].

Context synchronization: This module gets the context information stored by WF Client and sends it to WF Server. The server side stores the data in a data base. We transform the WF Server in a community using Google Friends API.

IV. EXPERIMENTAL RESULTS

This section discusses some experiments executed in the testbed previously shown in Figure 5. In this figure there are: a home agent, a correspondent node, the WF Server and the mobile node. This testbed is a NGN environment with three WLANs using Wi-Fi technology. The idea is to make available a testbed where the mobile user can achieve more than one wireless network at some area (e.g. at instant $\mathbf{i_3}$, in Figure 5, the user has two options WLAN **B** or **C**). The environment is an IPv6 network using a mobile IPv6 implementation [12] to manage the mobility at network layer three. The home agent is at WLAN **A** (2000:a::/64), the correspondent node and WF Server are at another wired network (2000:e::/64).

We did six experiments, five with UDP and one with TCP using *iperf* tool on Linux. The *iperf* was configured in server mode, at the correspondent node, and in client mode, at mobile node. With UDP the throughputs were 2, 4, 6, 8 and 10 Mbps, and with TCP the tool tried to use the maximal capacity of the connection. The main aim of the experiments was the comparison between the WF mechanism introduced in this work, and the reactive mechanism typically available in ordinary operational system. This reactive method selects the next access point using only signal quality of the networks available, and ignores the user's behaviors. Mainly works, in the specialized literature, use just QoS parameters. In this case, these approaches probably will have the same behavior of the reactive method in our testbed.

The numerical results are shown in Table 3. The mobile IP handover latency with UDP was varying of ~4 to 4.9 seconds and with TCP was ~14 seconds. This difference was expected and probably occurred because of the overhead of the acknowledgment mechanism implemented in TCP that increases significantly the performance of the buffers management at the home agent. There are amount of works that improve the performance of mobile IP, but in this paper we just used an implementation to keep the connection between the mobile node (*iperf* in mode client) and the correspondent node (*iperf* in mode server) after the handover. Our mechanism try to reduce the offline time of the mobile user, as is shown in Figure 8 and 9.

Table 3. Experimental results

Experiment	Handover Lantency (s)	Standard Deviation	Offline WF (s)	Offline Reactive (s)
UDP 2 Mbps	4.40	0.223	4.40	8.80
UDP 4 Mbps	4.90	0.821	4.90	9.80
UDP 6 Mbps	4.64	0.350	4.64	9.28
UDP 8 Mbps	4.20	0.908	4.20	8.40
UDP 10 Mbps	4.06	0.439	4.06	8.12
TCP max.	13,80	1.890	13,80	27.60

In the first figure, we have throughput and signal quality (y axis) in function of time (x axis), showing the results of 4 Mbps UDP flow experiment, using the WF and the reactive mechanism. The WF method exchanges the network at ~6 s (signal quality 34%), from WLAN **A** to WLAN **B** that is the best choice in this route. Although, the reactive method exchange from WLAN **A** to WLAN **C** at ~14 s (signal quality ~23%), and do another handover at ~37 s (signal quality ~23%), from WLAN **C** to **B**.

In the experiment with TCP trying to use the maximal capacity of the WLAN, the general behavior of the two methods were similar to the behavior observed with UDP, as seen in Figure 9. In this figure, the WF mechanism did the handover, from WLAN **A** to **B** at ~4 s (signal quality ~30%), and keep associated to this network in the remaining route. On the other hand, the reactive mechanism did the handover at ~13 s (signal quality ~22%), from WLAN **A** to **C**, and exchanged again at ~41 s (signal quality ~24%), from WLAN **C** to **B**.

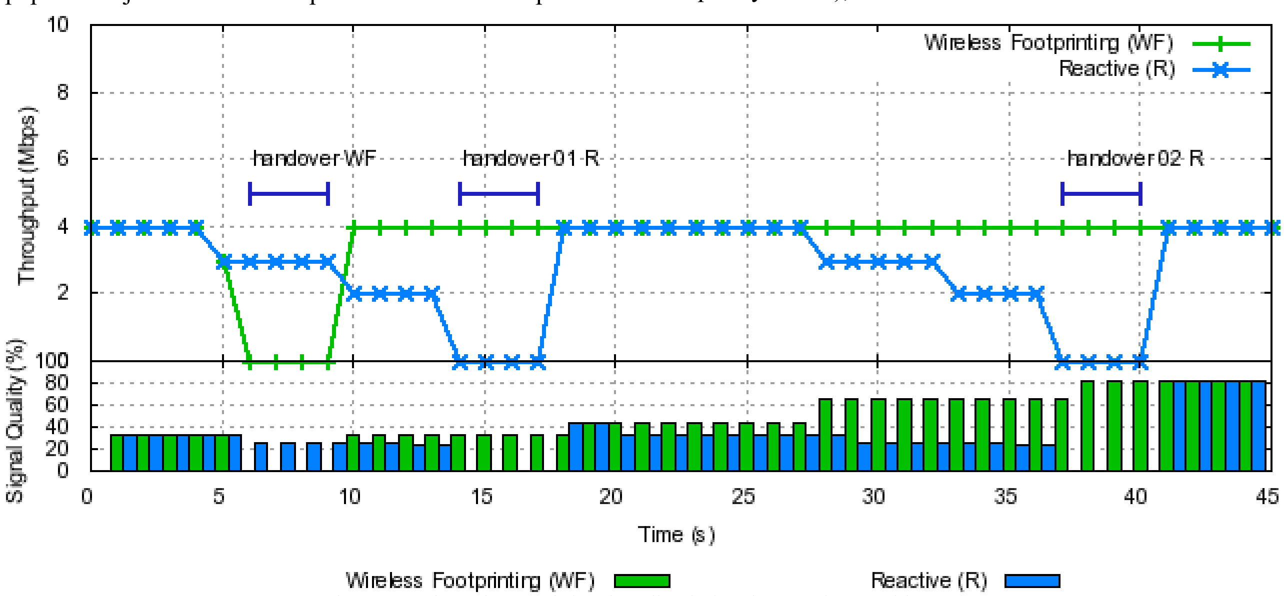

Figure 8. Throughput and signal quality during the experiment with UDP

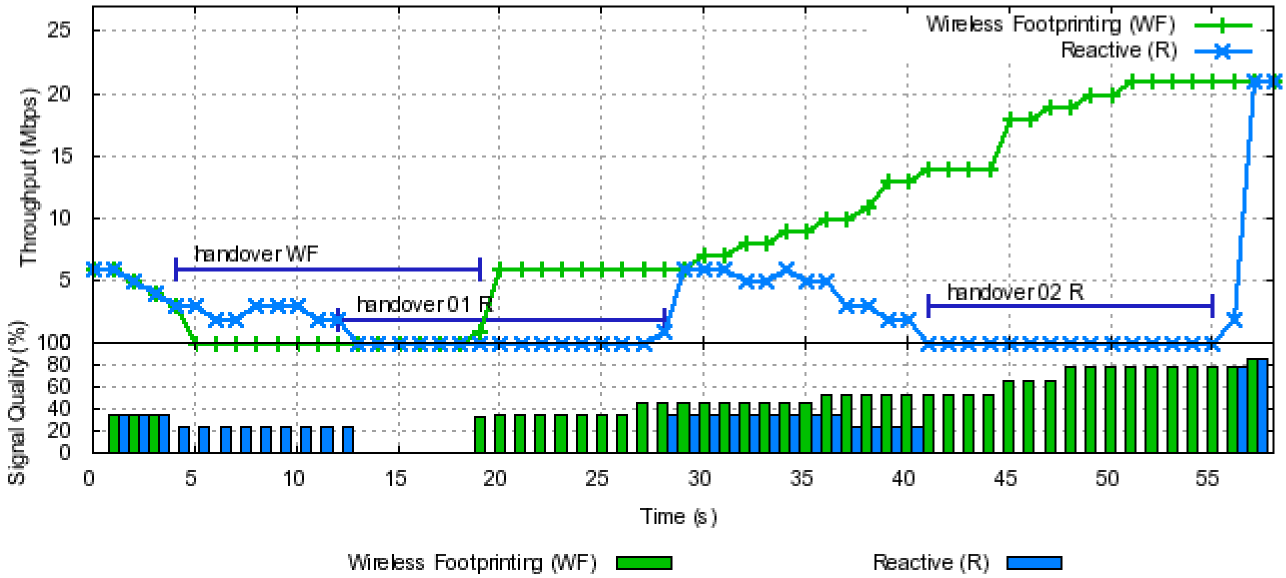

Figure 9. Throughput and signal quality during the experiment with TCP

The experimental results show that the proposed WF method avoids one handover in all cases. It means that the offline time of the user is a half than using just the reactive mechanism. The testbed was configured to represent a real NGN environment.

V. Conclusion

In this paper, firstly we discuss the main ideas related to the context-aware feedback-based mechanism that makes use of virtual communities for share connectivity experience. Secondly, we present in brief the main modules that have been implemented in a tool called Wireless Footprinting to validate the key ideas. Thirdly, we illustrate the experiments conducted and results obtained for comparing the proposed WF method and traditional reactive solution typically available in ordinary O.S.

The major contribution of this work is the introduction of the context-aware and feedback-based mechanism and the WF tool that achieves the challenge of implementing the proposed method. The experimental results show that the offline time of the user going through a known route could be improved significantly by using the WF method.

By means of the research reported herewith, we are closer to achieve the challenge of researching and developing tools to share connectivity experiences as social media. The current implementation uses common web technologies such as RSS Feeds and mash-ups towards realizing the ubiquitous IP connectivity vision.

VI. Acknowledgment

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References

[1] A. J. Nicholson and B. D. Noble, "BreadCrumbs: Forecasting Mobile Connectivity," Proceedings of 14th ACM international conference on Mobile Computing and networking. San Francisco, California, USA, pp. 46-57, June 2008.

[2] A. Rahmati and L. Zhong, "Context-for-wireless: Context-sensitive energy-efficient wireless data transfer," Proceedings of the Fifth International Conference on Mobile Systems, Applications and Systems (MobiSys '07), pages 165–178, San Juan, Puerto Rico, June 2007.

[3] G. Fodor, A. Furuskar and J. Lundsjo, "On Access Selection Techniques in Always Best Connected Networks," Proceedings of the 16th ITC Specialist Seminar on Performance Evaluation of Wireless and Mobile Systems. Antwerp, Belgium.

[4] L. B. Patanapongpibul and G. E. Mapp, "A Client-based Handoff Mechanism for Mobile IPv6 Wireless Networks," Proceedings of Eighth IEEE Symposium on Computers and Communications. Kemer-Antalya, Turkey, pp. 563-569, June 2003.

[5] D. Cheng, H. Song, H. Cho, S. Jeong, S. Kalasapur, A. Messer, "Mobile Situation-Aware Task Recommendation Application," International Conference on Next Generation Mobile Applications, Services and Technologies, pp. 228-233, September 2008.

[6] Z. Yu, et.al., "Supporting Context-Aware Media Recommendations for Smart Phones," IEEE Pervasive Computing, vol 5, Issue 3, pp 68 – 75, July-Sept. 2006.

[7] IEEE 802.21, "IEEE 802.21 Media Independent Handover," vol. 2006: IEEE 802.21, pp. http://www.ieee802.org/21/. Visited in June 2009.

[8] P. Hui, A. Chaintreau, J. Scott, R. Gass, J. Crowcroft and C. Diot, "Pocket Switched Networks and Human Mobility in Conference Environments". Proceedings of the 2005 ACM SIGCOMM workshop on Delay-tolerant networking. Philadelphia, Pennsyvania, USA, pp. 244-251.

[9] A. LaMarca, Y. Chawathe, S. Consolvo, J. Hightower, I. Smith, J. Scott, T. Sohn, J. Howard, J. Hughes, F. Potter, J. Tabert, P. Powledge, G. Borriello, and B. Schilit. "Place Lab: Device positioning using radio beacons in the wild". Lecture Notes in Computer Science – Pervasive Computing, Vol. 3468/2005, pp. 116-133.

[10] Y. Cheng, Y. Chawathe, A. LaMarca, and J. Krumm, "Accuracy characterization for metropolitan-scale Wi-Fi localization," Proceedings of MobiSys. Seattle, Washington, USA, pp. 233–245, June 2005.

[11] D. Cottingham and R. Harle, "Constructing Accurate, Space-Efficient, Wireless Coverage Maps for Vehicular Contexts," Proceedings of 4th International Wireless Internet Conference, ICST WICON. Maui, Hawaii, pp. 33-45, June 2008.

[12] MIPL. Mobile IP for Linux (MIPL). Developed by HUT Laboratory for Theoretical Computer Science - GO/Core project http://www.mobile-ipv6.org. Visited in June 2009.