RLoad: Reputation-based Load-balancing Network Selection Strategy for Heterogeneous Wireless Environments

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***Abstract* — In the current environment, network operators are trying to cope with the significant increase in data traffic by adopting different solutions to expand their network capacity. One solution would be the convergence of next generation wireless networks (e.g., HSDPA, LTE and WiMAX) which involve the closely interworking of the existing 2G/2.5G/3G networks with the new next generation networks in terms of handover and network selection. However, as a result, the diversification in mobile devices and the heterogeneity of the wireless environment make the seamless always best connectivity of the mobile users a challenge for the service providers.**

To this extent, we propose RLoad a novel Reputation-based Load-balancing Network Selection Strategy for heterogeneous wireless environments built on top of the IEEE 802.21 Media Independent Handover (MIH) standard. The proposed solution makes use of a reputation-based mechanism to select the most appropriate set of networks for the mobile user and a load balancing mechanism to distribute the traffic load among the networks by making use of the Multipath TCP (MPTCP) protocol. Preliminary simulation results show the significant benefits of the proposed RLoad solution.

Keywords— network selection solution; heterogeneous wireless network; MIH; MPTCP; reputation mechanism

I. INTRODUCTION

The "optimally connected anywhere, anytime" vision was first introduced in June 2003 by ITU in Recommendation ITU-R M.1645 [1]. The aim was to connect different radio access networks via flexible core networks in order to provide seamless, transparent and Quality of Service (QoS) enabled connectivity to the mobile users.

Moreover, in order to ensure QoS and to facilitate handover between different Radio Access Technologies (RATs), the IEEE 802.21 Media Independent Handover (MIH) Working Group [2] (Jan 2009) considered and interoperability aspects between heterogeneous networks and developed the standard referred to as the IEEE 802.21. This standard enables the handover optimization by providing a media-independent framework and the associated services. However, the standard only offers support for the handover process without defining a network selection algorithm which is a major part of the handover process.

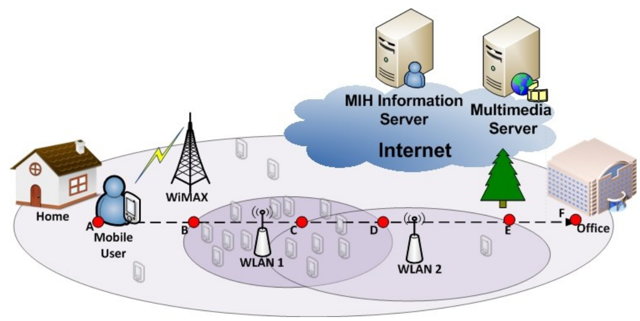

Fig. 1. Heterogeneous Wireless Environment – Example Scenario

In this context, the "Always Best Connected" (ABC) vision emphasizes the scenario of a variety of RATs that work together in order to provide a global wireless infrastructure in which the end users will benefit from an optimal service delivery via the most suitable wireless network that satisfies their interests [3] among all the available wireless networks. An example of such heterogeneous wireless environment is illustrated in Fig 1, where a mobile user is roaming through a heterogeneous wireless environment while on the move from home to office. In this context, there is an increasing desire to enable the ABC paradigm within today's heterogeneous wireless network environment [4].

However the ABC problem combined with the problem of network selection decision is a complex one, with the main challenge of trading-off different decision criteria (e.g., service class type, user's preferences, mobile device type, battery level, network type, network conditions, time of day, price, etc.). This becomes further complicated by the combination of static and dynamic information involved, the accuracy of the information available, and the effort in collecting all of this information with a battery, memory, and processor limited device.

To this end, we propose RLoad, a reputation-based load-balancing network selection strategy for heterogeneous wireless environments, which is built on top of the IEEE 802.21 MIH architecture to enable the seamless handover and information exchange between the heterogeneous wireless networks. The proposed solution makes use of the multi-user involvement in order to build a reputation-based system that selects the most appropriate set of networks. A traffic load-balancing mechanism is proposed that makes use of the MPTCP protocol in order to balance the traffic among the set of networks and find the best trade-off between QoS, monetary cost and device energy consumption.

II. RELATED WORK

To date there has been extensive academic research related to the *Always Best Connected* paradigm and various solutions have been proposed in order to address this problem of ensuring always best connectivity and always best experience in a multi-user multi-terminal multi-network wireless environment. For example, Sharma et al. [5] propose a vertical handoff system between WLAN and GPRS links by using an extension of the Mobile IP protocol. The solution is transparent to the end-user and the switch between WLAN and GPRS links is done based on the WLAN availability.

Additionally, the adoption of the IEEE 802.21 MIH standard enabled the optimization of handover between heterogeneous networks. However, the framework itself does not provide any network selection algorithm. To this end, various researchers build their solution on top of the IEEE 802.21 MIH architecture [4][6-7]. A number of researchers in [6-7] have enhanced the MIH Information Server to accelerate vertical handover procedures to support the network selection and seamless handover.

Moreover, to address the problem of network selection decision, reputation systems have been studied and deployed on the wireless environment being useful for cooperation scenarios and decision making problems [8]. The authors in [7] make use of a large set of parameters that map the QoS and QoE to a network reputation value for the vertical handover decision-making. In [9], the authors propose a reputation-based network selection mechanism using game theory. The reputation is built based on individual user experience and the mechanism is integrated into an extended version of the IEEE 802.21 model.

With the advances in mobile devices, having a multi-interface connected device becomes common. For example, Rodriguez et. al in [10], make use of the striping techniques in order to multiplex the data across multiple interfaces. The authors argue that this technique can provide a several-fold improvement in TCP throughput over the single interface scenario. In [11], the authors demonstrate the feasibility of TCP flow migration in the real device and the real environment. The Multipath TCP (MPTCP) protocol represents an extension of the classic legacy TCP. It allows multiple sub-flows to be set up for a single connection session [12]. MPTCP is connection-oriented and allows concurrent utilization of current hosts' multiple interfaces and access technologies to improve QoS parameters [13], especially for heterogeneous wireless networks. Chen et al. [14] proposed a mechanism that offloads the data stream between two network interfaces to balance the QoS and energy consumption on the mobile device in a heterogeneous wireless environment.

To this extent, this paper proposes RLoad - a novel reputation-based load-balancing network selection strategy for heterogeneous wireless networks, with the main contributions as follows:

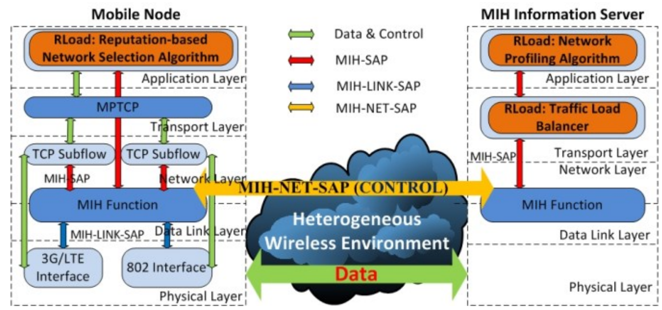

Fig. 2. RLoad Architecture

- a reputation-based network selection mechanism that computes a network reputation value based on the performance information gathered from the currently connected users.
- a dynamic load-balancing mechanism that distributes the traffic among the set of networks generated by the reputation-based network selection mechanism.
- the proposed RLoad mechanism finds the best trade-off between the QoS, monetary cost and the energy consumption of the mobile device.

III. SYSTEM ARICHITECTURE

The proposed RLoad framework block-level architecture is illustrated in Fig. 2. RLoad is distributed and consists of a server side component (MIH Information Server) and a client side component (Mobile Node). The RLoad architecture is built on top of the IEEE 802.21 MIH standard, thus both system components are MIH-enabled entities.

The MIH framework defines a cross-layer MIH function (MIHF) as a logical component between the network layer and the link layer [2]. Each of the MIH-enabled entities contains a cross-layer MIHF. This function provides Service Abstraction Points (SAP) acting as an abstract interface between a service provider and a user entity. User entities at higher layers employ the MIH-SAP to control or to monitor the link-layer entity and the MIHF uses the MIH-LINK-SAP as an interface together with the link layer to translate the information received from the MIH-SAP. The remote MIHF entities use the MIH-NET-SAP to exchange the information with the MIHF [3].

At the client side, the Mobile Node integrates a reputation-based network selection mechanism, which stores the list of the candidate networks together with their reputation values. The network reputation value is computed based on the QoS parameters and by defining a utility function. A set of suitable target networks is then provided. MIH-NET-SAP is used to exchange information with the MIH Information Server via the current serving networks. At the server side the Network Profiling Algorithm stores information about the network performance, and is based on the joint collaboration of the users within the network. Thus the MIH Information Server gathers the performance information feedback from multiple users within the network and computes the performance factor for that particular network. The Traffic Load Balancer uses this information in order to distribute the traffic among different network interfaces. This is done by using a weighted function that finds the best trade-off between the QoS, monetary cost and the energy consumption of the mobile device.

IV. RESULTS AND ANALYSIS

In our previous work [4], we proposed a reputation-based network selection (RNS) mechanism that enables the selection of the best value network for multimedia transmission. The performance of the RNS was evaluated by simulations, using Network Simulator 3 (NS-3) version 3.15 and compared against a classic Network Selection algorithm (Classic NS) that will always select the free hot spots. RNS was analyzed using the scenario illustrated in Figure 1, where a regular mobile user travels from home (point A) to the office (point F). On the way to the office the MN passes through the coverage area of several different radio access technologies (e.g., WiMAX and WLAN) at a speed of 1m/s. Both WLAN 1 and WLAN2 are assumed to be free hot spots with WLAN 1 heavily loaded. Moreover it is assumed that the MN is accessing interactive multimedia services at a data rate of 2Mbps.

Based on the proposed data, the Network Reputation Algorithm calculated the sequence of reputation values for each network, and listed the results in the following order: WLAN2 >WiMAX>WLAN1 [4].

Hence, based on the reputation value, the mobile device using the RNS scheme did not execute handover to WLAN1 at point B but to WLAN2 at point C instead. Alternatively, the classic NS scheme made the mobile device to handover to WLAN1 at point B and to WLAN2 at point D.

Fig. 3 shows the loss rate of the mobile device using the RNS scheme and the classic NS scheme. By using the RNS scheme, the mobile device recorded 26% decrease in packet loss rate in comparison with the classic NS scheme. Fig.4 illustrates that by enabling RNS the MN can achieve up to 44% increase in throughput in comparison with the classic NS scheme.

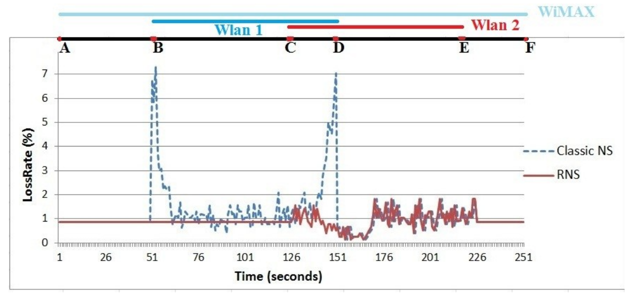

Fig. 3. Packet Loss Rate [4]

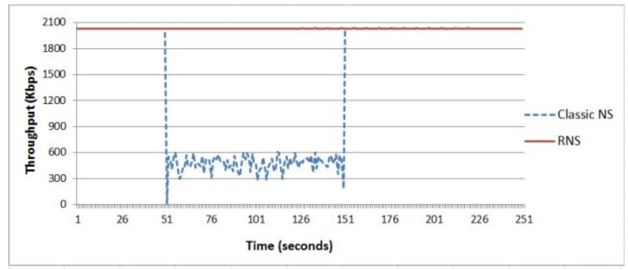

Fig. 4. Throughput [4]

V. SUMMERY AND FUTURE WORK

This paper proposes RLoad, a reputation-based load-balancing network selection mechanism for heterogeneous wireless environments. The preliminary results show the benefits of using a reputation-based network selection mechanism, achieving up to 44% increase in throughput in comparison with a classic network selection algorithm. As part of future work, we plan to demonstrate the benefits of the load-balancing mechanism that enables the traffic distribution among different RATs and achieves an optimal trade-off between QoS, monetary cost and energy consumption of the mobile device.

ACKNOWLEDGMENT

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