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Unwired: A Simulation Test-bed for Mobile P2P Live Streaming

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***Abstract*—The success of peer-to-peer live video streaming in wireline networks has inspired the development of mobile peer-to-peer streaming technologies. However, the traditional peer-to-peer live streaming techniques have been found to perform sub-optimal in wireless networks. Furthermore, the increasing energy consumption in wireless networks due to inefficient communication protocols has resulted in the need to develop greener, more energy efficient communication solutions. Therefore, we present Unwired, an OMNet++ based simulator for the development of mobile peer-to-peer live video streaming techniques. We have built upon the DenaCast simulation framework for peer-to-peer live streaming to include wireless peers. The major contributions to the existing framework are in the form of introducing mobility on the wireless peers, enabling hand-offs for the mobile peers and providing a power component on each mobile peer to monitor the energy consumption by the peers during video streaming. We simulate a hybrid network including both wireline and wireless peers and study the similarities and differences in the performance of the two types of peers. Finally, we explain the utility of the power component in the future development of energy efficient communication protocols for wireless networks.**

***Index Terms*—Energy Consumption, Mobile Peer-to-Peer Live Streaming, OMNet++, Simulation.**

I. Introduction

Mobile video traffic is growing rapidly with yearly growing rates of more than 50% according to Cisco [6]. The success of peer-to-peer (P2P) live video streaming in wireline networks has recently led to the development of mobile P2P live streaming applications. SopCast for Android [10], RapidStream [7] and TVU Player [11] are examples of currently existent mobile P2P live streaming applications. However, the traditional live streaming techniques have been found to perform suboptimal in 3G networks [9]. Hence, a need arises regarding the development of new protocols for P2P live video streaming in mobile networks.

Design and test of new application protocols is widely studied under two mutually exclusive tracks, empirical analysis and by the means of simulation. Empirical analysis involves implementation of the design under test and improvisation based on measurements conducted by experimentation in real scenarios. Examples of such measurement campaigns are the studies conducted by Kim *et al.* [12] and Eittenberger *et al.* [9], wherein the performance of mobile peers is characterized by measurements. They are obtained by traveling through metropolitan areas while disseminating content over wireless networks. Although such an analysis gives the most accurate results, it is time consuming and quite laborious. Hence, empirical analysis is often avoided in developmental experimentation. Thus, the development of a simulation test-bed is vital for the deployment and performance evaluation of prospective protocols.

There are many P2P live streaming simulators available, for example, OPSS [5], PeerSim [15], SSSim [3] etc. However, all of the available platforms share one common shortcoming. They are built on top of a very simplified model of the underlying transport network. Typically, the transport network is mainly characterized by packet loss and latency. Such an oversimplification makes it unrealistic to implement cross-layer design approaches and to investigate the influence of wireless networks on the performance of these applications. To address this shortcoming, we have built *Unwired*[1]. Our framework is based on DenaCast [16], which is a widely used simulator for P2P live streaming in a wireline network with stationary peers. DenaCast uses OverSim [4], an OMNet++ [2] based overlay and P2P network simulation framework, in the overlay and INET [1], an OMNet++ framework for communication networks, as underlying transport network model.

II. P2P Streaming in Mobile Scenarios

The migration of P2P video streaming applications to a mobile environment requires certain adoptions, since mobile devices are battery powered and have in general less computing power compared to standard PCs. In addition, P2P applications running in a mobile environment encounter different network dynamics compared to a "wired" scenario. Although next generation mobile networks, like LTE, strive to provide broadband-like downstream capacity, hand-overs and the fluctuating link quality negatively affect the transmission performance of P2P applications [8]. Moreover, the protocols of current P2P applications even increase the rate of control

[1]The presented framework is publicly available at https://sites.google.com/a/iith.ac.in/maaz/codes.

messages due to connection disruptions, and thereby, produce more signaling overhead [9].

In the following we identify requirements that these new factors, i.e., mobile devices and wireless networks, impose on P2P applications. These requirements can be coarsely divided into three domains: The first domain is given by the *data transport* in wireless networks. Contrary to wireline networks, applications operating in wireless networks may have to cope with various new disturbances: Comparably higher packet loss, dynamically changing and unstable link conditions, e.g., caused by signal fading or disruptions occurring during handoffs, fluctuating latency etc. The network heterogeneity might comprise a variety of access technologies, like 2G networks GPRS, EDGE (2.5G) or third generation UMTS / WiFi networks. Moreover, the uplink traffic is more expensive in terms of energy consumption and the wireless infrastructure may be less powerful.

The second domain consists of challenges imposed by the usage of *mobile devices*. As already mentioned, mobile devices suffer from limited computing resources and are restricted by their battery, which results in an increased failure probability. Hence, tracking the energy consumption by each mobile node in a network is of key interest in benchmarking the energy efficiency of a P2P live video streaming protocol. Moreover, the device heterogeneity and the limitations of mobile OSs constitute another obstacle that needs to be addressed.

The third domain comprises of well-known problems for *P2P systems*, which are fundamental, but are not specific to the mobile usage. These include, for example, NAT traversal, security considerations, free riding, attacks, like denial of service or content poisoning, content right management etc. However, it might be necessary to solve some of these problems in a different manner as opposed to the already established solutions for their wireline counterparts.

To summarize, mobile usage and wireless networks impose new conditions on P2P applications. Mobile peers are heavily limited by their battery lifetime and since communication protocols, which are not adapted to wireless networks, increase the energy consumption, the need arises to develop more energy efficient communication solutions. Furthermore, the protocols must be able to identify problems occurring in wireless networks and on mobile devices. That means, P2P protocols must be able to adapt dynamically to changes of the network conditions, like unstable links and disruptions, occurring during handovers, resulting from link breaks or by discharged batteries. In addition, the protocols must be streamlined to avoid unnecessary interactions and traffic as much as possible due to the battery restrictions.

To address these requirements, we have enriched the P2P streaming simulation framework DenaCast to incorporate a wireless network and mobile peers. The DenaCast framework in its current state does not allow the simulation of mobile nodes. Their introduction in a live streaming network significantly changes the network topology due to frequent hand-offs between access points. Recent P2P live streaming protocols are prone to any changes in the network structure due to hand-offs. Thereby, the effect of hand-offs on the performance of a live video streaming protocol needs to be studied by the means of simulation. Our extension enables the investigation of new P2P streaming protocols and data dissemination techniques specifically tailored for the requirements of mobile scenarios.

III. Unwired

Unwired is an extension of DenaCast to facilitate the simulation of mobile peers and perform real-time energy consumption measurements. It employs a similar application structure to that of DenaCast and markedly differs in the following respects. Unwired incorporates a hybrid wireless-wireline transport network, the so called *underlay*, it introduces mobility, hand-offs and includes a battery module on the mobile nodes.

All nodes in DenaCast use the point-to-point protocol (PPP) provided by the INET framework for the communication. PPP is a complex protocol with strong support for link configuration and maintenance. However, the INET model of the PPP ignores those details, and only performs simple encapsulation, decapsulation and queuing. This high level of physical abstraction does not account for real-time parameters like bit error rate, transmission data rate etc. Yet, these parameters are of primary importance in simulating a wireless data transmission scenario because of the varying channel quality index and the loss of data packets due to relatively higher bit error rates.

A. Underlay In Unwired

Unwired uses the INET framework as underlay. Among other things, INET comprises a fully implemented TCP/IP stack. Figure 1 shows a high-level view of the various components in the Unwired simulation framework. The nodes in an Unwired network can be classified into three types as *Backbone Routers*, *Access Routers* and *Overlay Nodes*. A typical P2P live video streaming scenario in Unwired is depicted in Figure 2. A mesh of routers, connected through PPP links forms the backbone of the Internet. The backbone routers are connected to access routers, which function as access points for the overlay nodes in the network. In the following, we elaborate on the structure and functioning of the different types of nodes.

B. Backbone Routers

A mesh of connected routers serve as the backbone of the Internet for the P2P live video streaming network. The structure of the Internet is independent of the type of end-user terminals being wireless or wireline. The backbone routers are connected to each other and to access routers through PPP connections. Alternatively, the backbone routers can also be connected to each other by an Ethernet interface. It includes a queue, an encapulator-decapsulator and a media access control (MAC) layer. CSMA/CD is used as the MAC protocol. An *interface table* maintains the list of all physical interfaces on a backbone router. The physical interfaces forward the received packets to the *network layer*, which is also provided

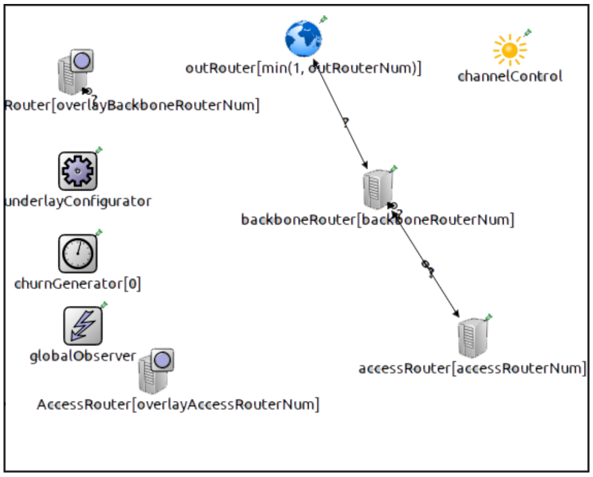

Figure 1. A high-level prespective of the network architecture in Unwired.

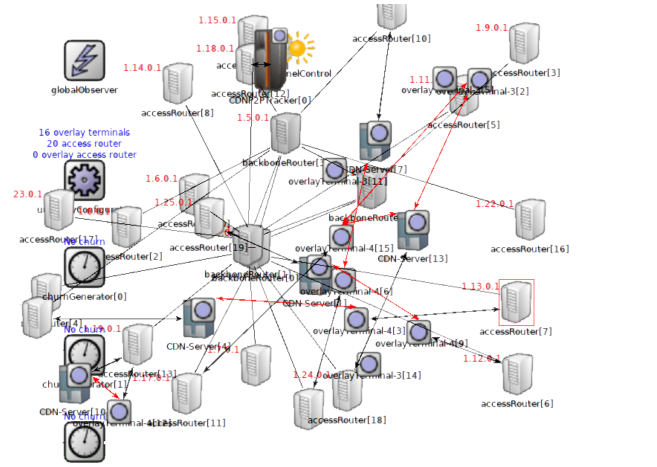

Figure 2. P2P live video network as simulated in Unwired

by INET framework. The list of all routes on a backbone router is maintained in the *routing table*. All the data and control packets are routed by the network layer using the routing information from the routing table. A special component called *namTrace* is used on the backbone routers to maintain a log of all the routed packets. Furthermore, the module can generate packet capture (pcap) files for off-line analysis.

C. Access Routers

The access routers serve as a relay between the peers in the P2P live video streaming network and the Internet. To accommodate mobile peers in the network, access routers are equipped with an additional wireless local area network (WLAN) interface, apart from the physical PPP and Ethernet interfaces. Access routers connect to the mobile peers using a physical WLAN interface. To connect to wireline peers and the core routers in the back-end, they use PPP and Ethernet interfaces. The *interface table* maintains a list of all physical interfaces and connections. Routing is performed in the network layer using routing entries of the routing table. The structure of the network layer and the physical PPP and Ethernet interfaces in an access router are the same as that of a backbone router. The module *accessNet* helps to establish a connection between an access router and newly spawned nodes. Additionally, each access router in Unwired contains the physical and MAC layer architecture of the wireless interface. The physical layer, *radio*, is modeled as a WLAN radio using the radio model of the IEEE 802.11 standard. The MAC layer and the data link layer are represented by the modules *mac* and *mgmt* respectively (see Figure 4). The WLAN interface in an access router uses the IEEE 802.11 ad-hoc MAC from the INET framework. An ad-hoc network features a small group of devices in close proximity, which communicate with each other in a P2P fashion. Ad-hoc connections involve fewer authentication steps and are usually established faster compared to their infra-structural counterparts. Furthermore, the functioning of an ad-hoc sub-network in a P2P fashion makes the usage of the ad-hoc MAC a better choice in comparison to an infra-structure MAC.

D. Overlay Nodes

Depending on the function they serve, the overlay nodes are classified either as *CDNP2PTracker*, *CDN-Server* or *overlayTerminal*. In the following we present the individual structure of these different types of overlay terminals.

1) CDNP2PTracker & CDN-Server: The *CDNP2PTracker* serves as the tracker server for the P2P live video streaming network. The tracker server keeps track of the overlay topology, video chunk requirements of all the peers and other important network data to enable successful P2P video streaming. The *CDN-Servers* are the source of the video content in a P2P live streaming network. They function as video servers. The video server and the tracker server communicate with other peers in the network over the Internet. The architecture of both remains unchanged by the introduction of mobile peers to the live video streaming network. Therefore, the have the same architecture in Unwired as in DenaCast.

2) Overlay Terminals: The *overlay terminals* in Unwired are the peers of a P2P live video streaming network. A typical Unwired simulation network has both mobile and wireline peers. The composition of a hybrid network in terms of the fraction of mobile peers can be varied in different simulation runs. The structure of the wireline peers in Unwired stays the same as in DenaCast. Figure 3 shows the architecture of a mobile peer in Unwired. The *mobility* module of the INET framework enables mobility for peers. To simulate the movement of a mobile peer in a city, we use the *RandomWPMobility* mobility type, a modification of the mobility model defined by Lutz [14], which was originally designed to simulate radio links in 4G networks. In this model a peer moves along a randomly chosen line segment in the specified simulation area. The speed of the peer is chosen according to a uniform distribution. Mobile peers are equipped with a *battery* module to keep track of the energy consumption and thereby, evaluate the energy efficiency of the streaming

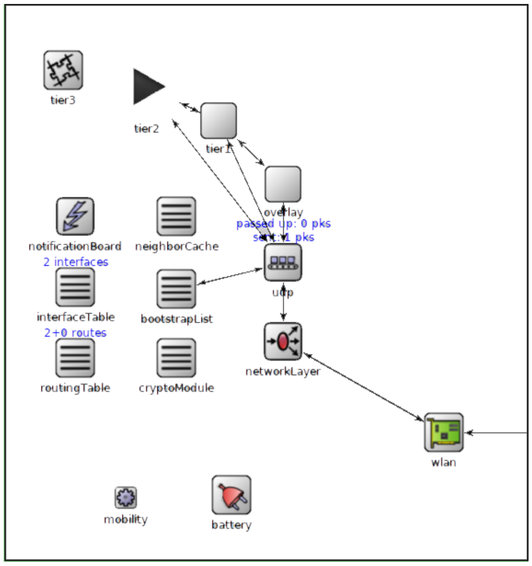

Figure 3. Architecture of a mobile peer in Unwired

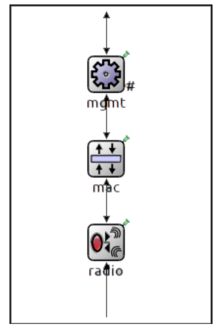

Figure 4. Physical and MAC layer architecture of the wireless interface of a mobile peer in Unwired

protocol. Section V elaborates in more detail on the working of the battery module. Both, mobile peers and wireline peers, use the UDP implementation of the INET framework as transport protocol for all communications in the P2P network.

Figure 4 shows the physical and MAC layer architecture of the wireless interface used in a mobile peer in Unwired. A mobile peer uses the INET model of the IEEE 802.11 WLAN standard in the physical layer. The MAC layer used in a mobile peer is a modification of the INET model of a IEEE 802.11 base station. This model of the INET framework has been modified to incorporate hand-offs by mobile peers.

IV. Hand-offs

This section explains the necessary modifications to enable the process of hand-offs in Unwired. Due to the movement of peers from the coverage area of one access point to another, hand-offs come into play. Unwired follows a soft hand-off scheme, wherein a peer connects to the geographically closest access router and then loses connection with the previously connected access router. Unwired uses a flat-faded wireless channel model. That means the received signal strength from an access router varies as a function of the distance between the access router and the mobile peer raised to a path loss exponent α. Depending on the environment being rural, urban or sub-urban, α varies between 2 and 4. In such a setting, the geographically closest access router is also the one with the strongest signal. Hence, to achieve a good approximation of the real scenario, we have implemented a hand-off that is based on the location of the closest access router.

The mobility module on a mobile peer keeps track of the geographic distance been the mobile peer and all the access routers. A hand-off occurs during motion, when the mobile peer gets closest to an access router other than the one it is associated to. After the new connection is established, the default gateway of the mobile peer is changed to that of the new access router and the routing tables of the new access router and previous access routers are refreshed to incorporate the changes of the network topology. These topology changes in the network are reflected in the MAC layers of the peers involved in the the hand-off process by updating the address of the associated access point.

V. Battery Module

One very important parameter in studying the performance of mobile peers in a P2P live video streaming network is given by the battery lifetime of the peers. A high energy consumption for live streaming is not desirable, because it quickly drains out the battery and thus, disconnects the peer from the streaming network. Hence, it is important to develop P2P live streaming protocols, which minimize unnecessary packet transmissions and thereby, increase the overall efficiency of the P2P network. To study the energy consumption and usage patterns of mobile peers, Unwired provides a battery module on the wireless peer, which periodically logs the consumed energy and the residual battery capacity. As INET does not provide a battery module, Unwired uses an integration of the battery module provided by the MiXiM framework [13]. The radio on a mobile peer operates in four different states, namely `SLEEP`, `IDLE`, `TRANSMIT`, `RECEIVE`. During the `SLEEP` state, the radio is switched into a low power mode, which amounts to a minimal energy consumption. In the `IDLE` state, the mobile peer is associated to an access point but does not transmit or receive any data. Packet transmission and reception during the radio states `TRANSMIT` and `RECEIVE` respectively, consumes significantly higher energy than the `IDLE` state. The energy consumption by a mobile peer during different radio states are determined during the simulation set up depending on the NIC under study. Fig 5 shows the consumed battery capacity of a mobile peer during simulation in Unwired. Peers with zero residual battery capacity are disconnected from the network and the network is dynamically reconfigured. To enable later off-line analysis, the energy consumption profiles of all mobile peers are stored in the simulation log files.

VI. Simulation Results

We have simulated a 100 node P2P live video streaming network using Unwired by varying the ratio of mobile peers

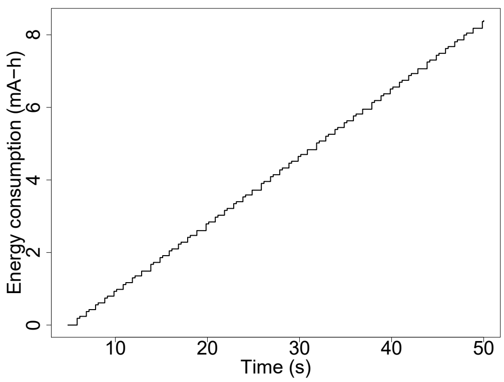

Figure 5. The variation of consumed battery capacity of an exemplary mobile peer during simulation in Unwired as a function of time

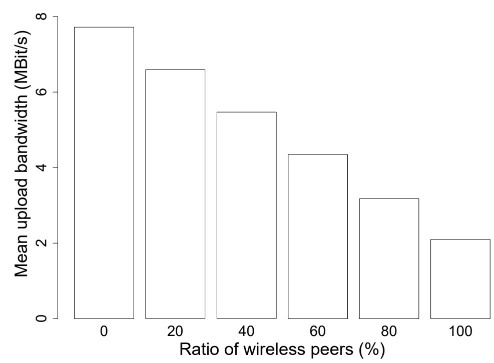

Figure 6. Mean upload bandwidth encountered with different ratios of mobile peers

to wireline peers from 0 to 1 in steps of 0.2. The simulation scenario is set to mimic the live video streaming in an urban region. Hence, the path-loss exponent α is set to 4. The mobile peers follow the random mobility scheme, *RandomWPMobility* with a parameters *minSpeed* and *maxSpeed* being 20 Km/h and 40 Km/h respectively. Fifteen access points are placed in a 1 Km $\times$ 1 Km grid and the simulation is run for 200 s. The Cisco Aironet Wireless PCI Adapter AIR-P121AG-E-K9 wireless NIC is used to model the radio. Hence, the nominal voltage of the battery driving the mobile peer is 3.3 V and the current drawn by the mobile peer during `SLEEP`, `IDLE`, `RECEIVE` and `TRANSMIT` radio states are 12.12 mA, 202.72 mA, 326.96 mA and 539 mA respectively. Table I summarizes the simulation parameters used for the evaluation. In the following we compare some exemplary performance metrics, which are vital for the future analysis of reliable P2P live streaming in wireless scenarios. Apart from the shown examples, many other metrics, like e.g., distortion, buffer and transmission delays, packet loss due to bit errors or late arrivals etc., can be evaluated too.

A. Trends in Upload Bandwidth

First, we study the trend in upload bandwidth used for the streaming of video content as a function of the ratio of mobile peers in the network. Figure 6 displays the diminishing mean upload capacity of the peer population inferred by the increase of mobile peers in the system. The observed trend of diminishing upload capacity can be explained. On the one hand, the upload capacity of mobile peers is smaller compared to their wireline counterparts. However, this is not the sole explanation for the steep decline. More importantly, the streaming protocol of Denacast, which implements the chunk scheduling mechanism as proposed in [17], was not yet adjusted to the requirements arising due to the mobile usage. Thereby, the streaming protocol is not able to adapt to the dynamic behavior of the wireless network and the total net upload bandwidth of the system degrades.

Table I
SIMULATION PARAMETERS USED FOR EVALUATION

S. No	Simulation Parameters	Value
1	Simulation Time	200 s
2	No. of Access Routers	15
3	No. of Peers	100
4	Mobility Model	RandomWPMobility
5	Minimum Speed	20 Km/h
6	Maximum Speed	40 Km/h
7	α	4
8	Carrier Frequency	2.4 Ghz
9	Nominal Battery Voltage	3.3 V
10	Radio Sleep Current	12.12 mA
11	Radio Idle Current	202.72 mA
12	Radio Receive Current	329.96 mA
13	Radio Transmit Current	539 mA

B. Trends in Startup Delay in Video Streaming

Another exemplary metric, we want to discuss, is given by the startup delay that peers encounter. The startup delay is the timespan between the initial request for the video and the start of the video playback. Figure 7 shows the mean startup delay, that the whole peer population encounters in relation to an increasing share of mobile peers. Even in a population comprising of 80 % mobile peers, the increase of the startup delay is negligible. However, if the ratio of mobile peers reaches 100 %, we observe a steep increase of the startup delay. Again, this observation can be explained by the higher upload capacity of wirelined peers and the ineptness of the streaming protocol. Though, it has to be noted that only 20 % of wirelined peers are able to supply sufficiently a share of 80 % of mobile peers without a drastic quality-of-service degradation. This might be taken as a good example of the inherent scalability of the P2P paradigm even in such a demanding mobile and wireless scenario.

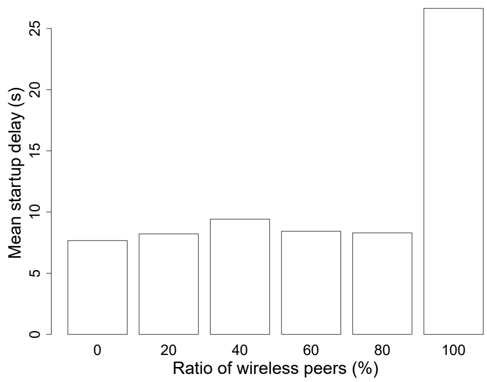

Figure 7. Mean startup delay encountered with different ratios of mobile peers

VII. Conclusion

We have presented Unwired, a first step towards the study of mobile video streaming P2P applications. In its current state, Unwired is an portable OMNet++ based simulator, which enables the versatile simulation and evaluation of P2P applications and protocols in mobile scenarios over wireless networks. We have explained in detail the structure and architecture of the different node types in the Unwired underlay. In addition, we analyzed the performance degradation of a P2P live streaming application developed for wireline networks as the fraction of mobile nodes increases.

The current physical and MAC layers of mobile peers are specified according to IEEE 802.11 standards. Regarding the growing popularity of Wimax and LTE standards, we intend to enhance this simulation test-bed to support Wimax and LTE standards in the physical and MAC layer. This will increase the relevance of the simulation environment to the real world scenario where mobile peers will be most likely subscribed to such access technologies. Node mobility patterns play a vital role in the performance of a wireless network. Therefore, it is of prime importance for the characterization of the mobile network's performance to develop mobility models that fit closely to real world scenarios. The development of mobility models to mimic the real time traffic flows in cities and movement of video streaming peers is another key area we intend to extend further.

The main aim of Unwired is to enable the development of application layer protocols for mobile video streaming. However, the inclusion of P2P patterns in the physical layer of the protocol stack of mobile standards will improve the network performance multifariously. Thus, a promising approach will be the development of physical layer protocols suitable for P2P live streaming. Furthermore, the alarming rate of increase of energy consumption in wireless communications networks is instrumental in magnifying the global energy crisis. A novel solution to this seemingly imminent energy drought is given by the development of energy efficient communication protocols. The comprehensiveness of Unwired in terms of minute details of all layers of the Internet protocol stack and the presence of a battery component for real time energy consumption logging, allows probing into cross layer optimization techniques for the development of green communication technologies.

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