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ABSTRACT

The escalation of municipal and community wireless networks (CWNs) has raised many questions about the most suitable business model, funding instrument, and service pricing policy for a specific community. Unlike traditional Internet service providers, these networks provide wireless Internet access for the purpose of boosting the social and economic development of the community at large. Therefore, such projects need customized business models and pricing policies in order to achieve these objectives. We propose a content-based pricing model where the price of wireless applications is an increasing function of the used bandwidth and a decreasing function of the provided packet delay. We used the Opnet simulation tool to validate the proposed pricing model. The simulation results show that network operators may charge users only for audio and video applications because of the high bandwidth they use compared to data applications. The proposed pricing solution considers the social and economic objectives of CWNs.

Keywords

Community and municipal wireless networks, Internet pricing, digital divide, socio-technical networks, business models.

INTRODUCTION

Hundreds of cities and communities all over the world including New York, Austin, Seattle, San Francisco, USA; Paris, France; Hamburg, Germany; and Turku, Finland have established their own wireless networks. The majority of these networks do not offer free service and many of them are not city funded, owned or operated. They also have a variety of funding models and pricing policies for these particular wireless networks (Abdelaal and Ali 2007; and Sege 2005). According to Sege, the network of St Cloud, FL, is publicly funded with economic development money. The Chaska network is city-owned and operated project funded with a debt instrument and offers service for a fee. Other cities (e.g., Philadelphia, PA) adopted a public-private partnership that allows service providers to use the city rights of way to install the system facilities and the city serves as an anchor customer in exchange for low-cost service access for municipal employees and low-income individuals. In this public-private model, cities share installation costs with private entities in exchange for service and revenue sharing. These types of networks have grown to be essential due to the perceived market failure to support adequate competitive connectivity alternatives particularly for rural and underserved communities (Lehr, Sirbu and Gillett 2004). Unlike commercial Internet services, community and municipal wireless networks should adopt business models and pricing policies that consider the following issues:

1) The objectives of these networks are to bridge the digital divide and sustain the social and economic development of the community.
2) These networks accept donations from the community, employ volunteers, and use public properties to install the system facilities. Therefore, the pricing policies of these projects should have social objectives.
3) While many advocates argue that the service should be for free, this solution may not fit all communities particularly with the next-generation hybrid networks which are a combination of fixed and mobile networks. In addition, these projects need to generate money to update the used technology and cover operation costs such as the leased T-1 lines.
4) Such wireless networks serve a broad range of users and transport a wide spectrum of data, voice, and video applications. Operators should differentiate between different types of users and consider the differences in the applications characteristics (Stiller, Reichl, Leinen 2000).

5) These projects should consider the diversity of customers needs in terms of bandwidth, quality of service (QoS), and security. It is important to note that satisfying customers' needs in the wireless domain is much harder than in the case of landline Internet. This is mainly because of the limited bandwidth, signal interference, user mobility, and high error rate in the wireless environment.

The realm of CWNs lies at the cross section between public, private, and nonprofit organizations and there is a heavy confluence between their social and technical aspects (Abdelaal and Ali 2007). In other words, these networks are socio-technical networks where community members volunteer and donate to build customized wireless networks to fulfill their needs and fit their circumstances. The concept of socio-technical networks represents the interactions between technologies and people where technologies are developed within a social world and supported by technicians and other skillful individuals (Kling, McKim, and King 2001). As opposed to the traditional Internet service providers, the majority of community and municipal wireless projects lack well-defined service pricing models and cost recovery policies.

The question we are trying to answer is how can we develop a pricing policy for municipal and community wireless networks that considers their issues?

We propose a content-based pricing model that would address these issues. Recently, content-based pricing policies have become a growing scientific interest focused on for both Internet and mobile services (Kivisaari and Luukkainen 2003). We investigate the resource requirements of wireless applications and develop a pricing policy based on these requirements. In particular, we propose a pricing model for CWNs' services where the service price is a function of the throughput and the packet delay of this service. This study would be a first step towards a pricing model for CWNs that incorporates applications' QoS parameters such as bandwidth, packet delay, jitter, packet loss, and security.

LITRATURE REVIEW

There are three main pricing mechanisms in practice for Internet services: fixed monthly fee, per-hour fee; and volume dependent fee (Stiller, Reichl, Leinen 2000). Current flat prices lack the necessary theoretical foundations that optimize fairness and efficiency to better reflect the very special characteristics of internet usages and diversity of applications. Mason and Varian (1994) proposes a usage-based pricing scheme where users offer how much they are willing to pay per packet and the clearance price in the market is determined based on that. This per-packet pricing scheme is not simple enough for users to understand and for operators to implement. Kivisaari and Luukkainen (2003) proposed a content-based pricing solution using service differentiation and the customers' willingness to pay. The authors argue that these two factors are important for price determination, price discrimination, content bundling, and revenue sharing between content and service providers. The authors used timeliness, personalization, and location information as factors to differentiate services. DaSilva (2000) argued that dynamic prices have the capability to maximize service revenue, achieve fairness among flows, interact with system congestions and achieve efficient resource allocation. According to the author, a price policy should have two dimensions: what factors should be captured in the price, and how to implement this price policy in a way that integrates user's behavior with network conditions. Keon and Anandalingam (2000) propose the congestion-discount policy that suggests giving customers discounts if they shift their traffics from high congestion periods to low congestion periods. The shadow-pricing scheme assumes that users offer the amount they are willing to pay for their traffic. Fishburn, Odlyzko and Siders (1997) have proposed a pricing model that considers product differentiation, network effects, customer criteria and product evolution. Pricing policies should be simple enough for users to understand and for operators to manage (Edell, McKeown, and Varaiya 1995). Nguyen and Armitage (2003) believe that Internet pricing should reflect economic, social, and technical factors. Our proposed solution considers these three factors. Dasilva (2000) classifies the Internet pricing policies into dynamic policies where prices adapt to current network utilization, and static policies where prices are independent of current network utilization. Gupta, Stahl and Whinston (1997) have proposed a priority-based pricing policy for Internet traffic. According to this policy, Internet services are classified into classes and given priorities for each class. Users are charged based on these priorities. There are three differences between Gupta et al. 's work and our work: we use simulation results to support our model; our model incorporates the resource requirements by applications, and it considers the social objectives of CWNs. In addition, the majority of Internet pricing literature did not use simulation results and real system parameters to support their hypothesis, and that what motivated us to further explore this area and support our model with simulation results. A survey on pricing Internet services based on economics and technology perspectives have been conducted by Nguyen and Armitage (2003). Another survey on economics-based Internet pricing and Internet economics has been conducted by Henderson (2000).

Abdelaal and Ali (20007) classified CWNs' business models based on their service pricing, stakeholders, value offering, target customers, and resource management for different types of community and municipal wireless network. They classified them into six categories: public utility; ad-supported, education-centric, community, public-private, and locationhosting. They also provided examples of these business models, elaborated on their components, and identified their advantages and disadvantages. Jamaluddin, Doherty, Edwards and Coulton (2004) have proposed a hybrid operating model for public WiFi hotspots that can be used for advertising. They suggested offering free WiFi access to the public in return for sending localized advertisements to their wireless devices.

PROPOSED PRICING MODEL

We assume that the service access is provided free of charge and users will be charged only for the content they transport via the wireless network. The proposed pricing model considers the used system resources by each application. In particular, the price will be determined based on the throughput of the application and the packet delay for this connection. The proposed pricing solution considers the fact that network applications have different system requirements as shown in Table 1. Our proposed pricing scheme is a usage-sensitive pricing one. In usage-sensitive pricing schemes, the service price is a function of the amount of traffic that flows through the network connection (Dasilva 2000).

We used the Opnet network simulation tool to validate the proposed pricing model. We conducted simulation experiments to obtain data about the system requirements (e.g., bandwidth, packet delay) for the simulated applications.

Bandwidth Requirements for Different Applications

Before discussing the proposed pricing model, we would like to provide a brief background on the technical requirements for different wireless application. Wireless applications require different QoS parameters due to their different contents. These parameters include bandwidth, packet delay (or latency), jitter (delay variation), packet loss, fairness, and security features that applications need in order to satisfy users. Bandwidth is the potential data rate per second that can be transmitted over a network link. Throughput is the actual transmitted data rate per second and it is proportional to the bandwidth capacity of that link. For instance, while low jitter is essential for Voice over Internet Protocol (VoIP) and video applications, VoIP can tolerate a reasonable packet loss rate without QoS degradation. On the other hand, data applications (e.g. emails, http) can tolerate packet delay but not packet loss (Baghaei and Hunt 2004; Bhargava, 2002). Inherently, Internet applications have particular system requirements as shown in Tables 1. These requirements are essential to meet user’s satisfaction and maintain the connection quality (ITU-T 2003).

	Type	Bandwidth	Delay
e-commerce, email, web-browsing	data	< 10 KB	2-4 s
Fax	data	~ 10 KB	few minutes
Videophone	Video	16-384kbit/s	<400 ms
Video-clips (or one way video)	Video	16-384kbit/s	< 10 sec
Conversational voice	Audio	4-64kbit/s	<400 ms

Table 1: System Requirements by Different Applications (ITU-T 2003)

Table 1 shows that video applications (e.g., videophone and real-time video) are bandwidth-intensive applications. These applications require up to 384kb/s. However, audio applications (e.g., conversational voice) require bandwidth of 4 to 64kb/s. Data applications (e.g., fax, www, email) require transmission rate of 10 kb/s.

THE PROPOSED PRICING MODEL

As discussed in the previous section, wireless applications have different bandwidth and delay requirements. Thse requirements should be guaranteed in order to satisfy users (ITU-T 2003). We propose that these different categories of applications (e.g., data, audio, and video) should be priced differently to reflect the amount of used bandwidth and provided QoS parameters, which is packet delay in this study. This is to consider bandwidth scarcity in the wireless domain and the differences between users with respect to the types of used applications and QoS requirements. We assume that the access to the service is free for all users. The network operators, however, charge users for the content of their used applications. Equation 1 represents the proposed pricing model where the price 'P_i' of service ‘i’ is an increasing function of the provided throughput 'T_i' for this particular service and a decreasing function of the provided packet delay ‘d_i ‘as shown in Equation 1. ‘b’ and ‘a’ are tuning pricing parameters that could be different for different networks and different types of users.

$$f(P_i) = bt_i - ad_i \qquad (1)$$

The OPNET simulation tool is used to obtain data needed to validate the proposed pricing model. We simulated a small community wireless network of ten nodes, shown in Figure 1. We ran all the simulation experiments for 13 minutes. The data rate provided by each node is 11Mbps. We simulated one video application, three audio applications, and three data applications. In particularly, we simulated a low resolution video conference (V); PCM quality speech (PQS); IP telephony (IPT); low quality speech (LQS); http/image browsing (HIB); Email (E); and remote logging (RL). We collected simulation results about two system parameters: throughput and packet delay (in seconds) as shown in Table 2. The simulated network provides best-effort service and no security services were provided.

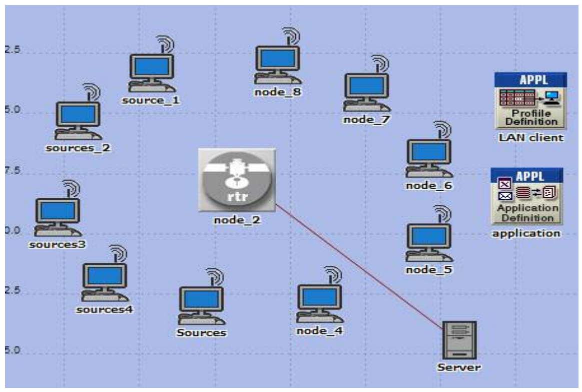

Figure 1. The Used Typology for the Simulated Applications

Experiment one: Throughput

The objective of this experiment is to investigate the used system resources (or throughput) by each application. Wireless networks are known of bandwidth limitations compared to landline networks and it is necessary to allocate this scarce resource efficiently. Table 2 and Figure 2 show that the throughput of the video application is much higher than the throughput of the data and audio applications. In addition, the throughput of audio applications is higher than the throughput of data applications. The throughput of video is 1,400,000 b/s while the throughput of the IP telephony, low quality speech, and PCM speech is 125,000 b/s, 48,000 b/s; and 290,000 b/s consecutively. The throughput of data applications is 80,000 b/s for http, 500 b/s for email, and 100 b/s for remote logging. The throughput of the email application is 0.00035 of the throughput of video applications and 0.0004 of that of the IP telephony application. Therefore, users should be charged more for video applications compared to audio applications. Similarly, they should be charged more for audio applications than data applications considering the used bandwidth or the actual delivered data.

	delay (sec)	Throughput (b/s)
V	0.23	1,400,000
PQS	0.01	290,000
IPT	0.01	125000
LQS	0.09	48,000
HIB	0.012	80,000
E	0.007	500
RL	0.01	100

Table 2. Packet Delay and Throughput for the simulated applications

In fact, the bandwidth that is used by data applications could be ignored if we price these networks based on the throughput of each application, letting us price the CWNs services only for audio and video applications.

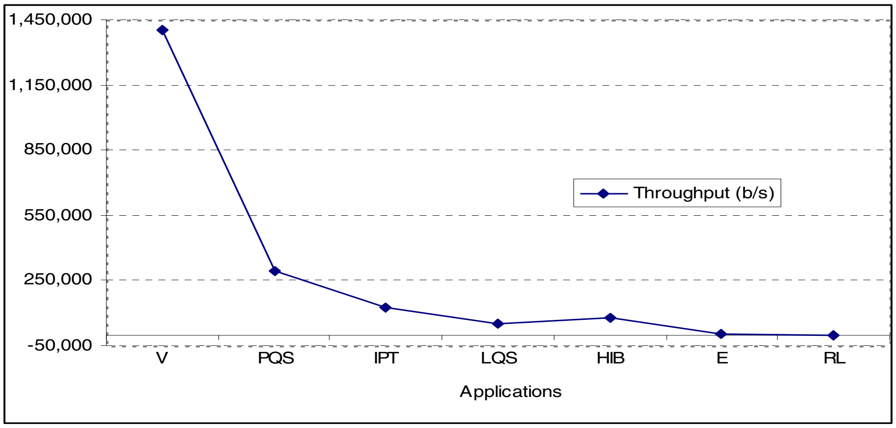

Figure 2. The Throughput of the Simulated Applications

Experiment two: Required Packet Delay

Some Internet applications are called real-time applications because they are very sensitive to packet delay (or latency) as shown in Table1. In this experiment, we obtained the end-to-end packet delay for the simulated applications, presented in Table 2 and Figure 3. The packet delay is 0.012 second for the http application, 0.007 for the email application, and 0.01 for remote logging. The delay of the video application is 0.23 second. The packet delay of the IP telephony and PCM quality speech is 0.01 second and 0.09 second for low quality speech. The delay of data applications is lower than the delay of audio applications and that of video applications is less than that of video. Clearly, the packet delay is a significant factor for these applications and it should be considered in the service price. High packet delay means low quality of service and that is why we propose that the service price is a decreasing function of the packet delay (or the QoS parameter).

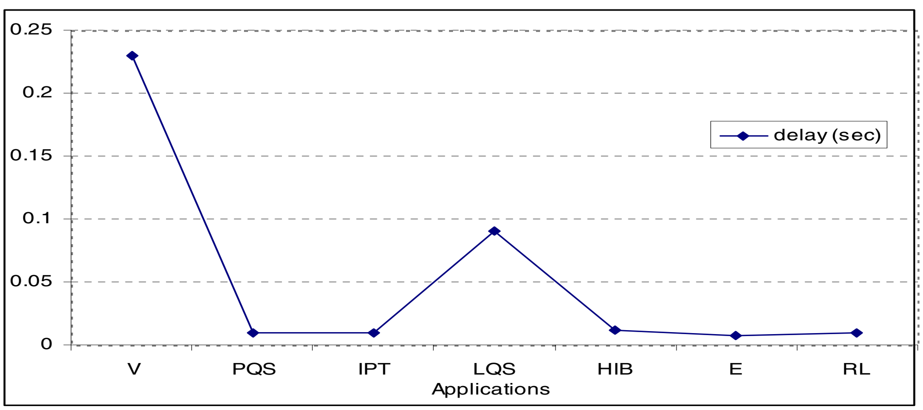

Figure 3. Packet Delay of the Simulated Applications

IMPLICATIONS FOR PRACTICE AND FUTURE WORK

The experiments show that data applications used the least amount of system resources, video applications use the biggest amount of system resources, and audio applications are in the middle of both. If we consider the used bandwidth by each application, we find that the system resources used by data applications are very low or even close to zero. In other words, data applications could be excluded if we price CWNs services based on the content of the services. Information about packet delay and used bandwidth by each application could be collected via an Internet accounting architecture in order to be used in this pricing model. Therefore, network operators should charge users a minimal (or zero) fee for data applications. This would help underserved communities and low income individuals to obtain the basic service (e.g. web browsing and email) at minimal cost or even free of charge. This model captures the applications properties and considers the limited system resources as well. This three-tier pricing model has the following advantages:

1) Big users who use high bandwidth would subsidize small users who use low bandwidth.
2) Charging for bandwidth extensive services (e.g., (audio and video) would generate revenue that would be used to update the technology and cover operation costs.

3) Providing the basic service for a small fee or free of charge would help bridging the digital divide and sustaining the economic and social development in the community.
4) The proposed pricing solution achieves fairness among users and efficient resource allocation.

Future work will focus on expanding this pricing model to include other QoS parameters such as packet loss, jitter, fairness, and security.

CONCLUSION

We proposed a content-based pricing model for community and municipal wireless networks that considers the social objectives of these projects and the technical requirements for wireless applications. In this model, operators provide users the service access for free and charge them for content only. In particular, they charge users based on the provided throughput and QoS parameters of the applications. According to the simulation results, network operators would have three-tier pricing mechanism: a relatively high rate for video applications, a medium rate for audio applications, and a very low rate for data applications. In other words, the basic service that includes only data applications would be charged minimal fee or just given for free. However, upgraded services that include voice and video applications should be for a charge because of the extensive bandwidth they use. This study is a first step towards a content-based pricing model that considers applications' QoS requirements including bandwidth, packet delay, packet loss, jitter, and security.

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