# Wireless Internet Competition: Municipal Wireless vs. 3G mobile Service


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## Abstract

*With an emphasis on creating ubiquitous Internet access to bridge the digital gap between location and access speed, the refinement of wireless technologies has it so that cities can reap the socio-economic benefits of the Internet. The 3rd generation (3G) and wireless fidelity (WiFi) are the two main wireless technologies which access Internet using wireless devices. Some major cities in the U.S. have either deployed or have future plans to roll-out city-wide broadband wireless network using WiFi technology. Even if 3G and WiFi have different origins and features, they will become competing wireless Internet access services in the near future. In this paper, using a game theory, the authors build a competition model of 3G and WiFi and demonstrate which technology will have a better market position and what an optimal pricing strategy is through equilibrium analysis. The authors found that in the equilibrium analysis, WiFi could have a better market position in the future. On the other hand, by using a higher pricing strategy, the profit of 3G providers would be higher than that of WiFi providers. Finally, the municipal WiFi could be useful as a public Internet access method and prove to be competitive in this market with its attractive low pricing.*


## 1. Introduction

The wireless network technologies arena has witnessed a breakthrough with trendsetting innovations, particularly with 3G and WiFi services. According to Cellular Telecommunications & Internet Association's (CTIA) wireless industry report,[1] mobile phone subscribers in the United States are estimated to be over 229 million as of December 2006. This market penetration of 76% has highlighted the saturation of the wireless voice market, as the wireless broadband Internet access will be an essential service to many wireless users in the near future.

For the past several years, the U.S. wireless communications market has been moving towards the third generation (3G) technology from the second generation (2G). The 3G and 3.5G wireless access systems provide data services along with voice and messaging capabilities. Some features of 3G services (using CDMA-2000 and W-CDMA standards) and 3.5G (using HSDPA upgrade) include 3D games, video-conferencing, full motion videos, and high-speed internet access on roaming mobile phones [9]. There are four major national carriers in the U.S. wireless market: Verizon, Sprint PCS/Nextel, Cingular, and T-Mobile. While the former two carriers chose CDMA-2000[2] as their 3G network technology, the latter two chose W-CDMA. The 3G technology focuses on major metro areas with remaining areas still under the 2.5G[3] technology. T-Mobile deployed a WiFi (Wireless fidelity) network, well-known for its public 'Hot Spots.' Even if broadband wireless service is in its early stage, these two wireless Internet access technologies (3G and WiFi) are two main streams being deployed by the telecommunications carriers. While WiFi providers focus on crowded public areas such as airports, hotels, college campuses, and shopping malls, 3G carriers provide wireless Internet access to city-wide metro areas. Since 3G service emphasizes mobility in the large area and WiFi service emphasizes bandwidth in the Hot-Spot, two wireless Internet services are considered complimentary. However, in 2004, some of the U.S. city authorities, including Philadelphia and San Francisco, announced they would have a municipal wireless Internet access service using WiFi network to cover a whole city. Once the municipal wireless starts its business, both technologies could provide coverage to the same area, prompting these two technologies to turn their characters from complimentary services to competitive services.

There are many arguments as to whether the municipal wireless service will succeed or not. In this

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[1] http://www.ctia.org


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[2] CDMA2000 is the 3rd Generation solution, which is an evolution of an existing wireless standard.

[3] General Packet Radio Services (Cingular, T-Mobile) and 1x-RTT (Verizon Wireless, Sprint PCS/Nextel)

paper, the authors present a wireless broadband Internet access competition model with two different wireless Internet access platforms. The authors will apply the model to the Philadelphia and San Francisco cases and attempt to find which technology will have a better market position in the future, i.e. whether the municipal wireless service can overcome the 3G wireless carriers or not, and what is the optimal pricing level in the equilibrium.

## 2. Comparison of two Wireless Broadband Technologies

Despite many differences between WAN-based 3G and LAN-based WiFi, crowded public places, such as airports, hotels, and bookstores, are common target locations for both providers. Lehr and McKnight [6] compared the characteristics of the two platforms. While similarities between WiFi and 3G exist, given that both are wireless access technologies and broadband data services, their business models and deployment strategies differ. 3G is a mass-market offering on a subscription basis, its deployment and service provisioning is top-down, and it is based on central planning and operation, which is the traditional telecommunications carrier model. 3G carriers own their infrastructure including paid spectrum and 3G licenses and provide a vertically integrated, bundled service of voice and data. Like a wireline telecommunications service, 3G service needs a significant investment in its early stage and its coverage is large enough to cover a metropolitan area. More over, 3G carriers centrally operate and manage their own infrastructure. On the other hand, WiFi can emerge in a decentralized, bottom-up fashion. The WiFi service is a spin-off of what home users have been doing for a while to provide service across their home. As the time goes by, WiFi has been adopted by campuses and corporate communities to serve their individual needs. It has been several years since commercial providers tried to sell WiFi Internet access in the hotels, airports, coffee shops. In contrast to 3G, WiFi coverage is very small (0.05 miles radius from a WiFi access point) and the lack of centralized government causes network deployment to be less systematic. WiFi access points spring up here and there, one by one. The cost of WiFi infrastructure is much cheaper than 3G when considering licenses and spectrum fees which are a significant entry barrier. Therefore, there are lots of small sized WiFi providers. In addition, WiFi businesses use a revenue sharing model that works with both the WiFi service provider and the location owner.

The following table shows the comparison of main technology standard of each wireless broadband Internet access technology.

Table 1. Comparison of 3G and WiFi

| | 3G |
|---|---|
| Technology | CDMA 2000 1xEV-DO, HSDPA (3.5G) |
| Throughput | 400~700 Kbps up to 2 Mbps |
| Pricing | Unlimited Pricing |
| Spectrum | Licensed Band |
| Coverage | Wide-Area |
| Providers | Verizon, Sprint PCS/Nextel, Cingular |

| | WiFi |
|---|---|
| Technology | IEEE802.11a, 11b, 11g |
| Throughput | 4.4~6.6 Mbps up to 11Mbps<br>12.4~24.7 Mbps up to 54 Mbps |
| Pricing | Unlimited, Per-Day, Per-Hour Pricing |
| Spectrum | Unlicensed Band |
| Coverage | Local-Area |
| Providers | T-Mobile, Wayport, Boingo |

## 3. Current Wireless Broadband Market and Municipal Wireless

In the 3G mobile broadband market, two competing technologies exist: EV-DO (Evolution-Data Only), an evolution of CDMA 2000, and High Speed Downlink Packet Access (HSDPA), an evolution of W-CDMA. In 2004, Verizon Wireless and Sprint PCS/Nextel positioned themselves as pioneers in the 3G (EV-DO) mobile broadband market[4]. Although the current maximum throughput is 2 Mbps, its actual speed is known as 500 Kbps. After the introduction of Cingular’s 3.5G service (HSDPA) in 2006, the unlimited 3G Internet access price of EV-DO was reduced from $80 to $60 per month. The coverage of Verizon Wireless and Sprint is available in more than 100 major U.S. cities and the major U.S. airports. On the other hand, Cingular Wireless’s 3G service is only available in 16 major cities due to a late start [7]. In this paper, the authors only focus on EV-DO technology as a representation of 3G mobile broadband.

In the WiFi broadband market, IEEE802.11b is a dominant standard even with the introduction of IEE802.11g, a higher data bit rate standard [13]. The entry barrier for WiFi is not as that of 3G, due to the fact that WiFi can be accessed for free over the same unlicensed spectrum used for cordless phones, baby monitors and microwave ovens; additionally, its service area can be expanded spot-by-spot. Therefore, it is possible for WiFi to have a community-based free service or revenue sharing between infrastructure providers and

[4] There are 6 more regional providers: Ace Wireless, Alltel, Cellular South, Leap, Midwest Wireless, NTCH Inc.

location owners. However, this paper focuses on the commercial type of WiFi provider, i.e. wireless Internet service provider (WISP). T-Mobile USA, as the fourth largest U.S. wireless carrier, chose to provide wireless Hot-Spots using IEEE 802.11b/g technology instead of upgrading its data network from GPRS to HSDPA. There are now more than 7,500 T-Mobile Hot-Spots in the U.S., including major airports. Another WiFi provider, Wayport, has 12,000 Hot-Spots including 6,300 McDonald's[5]. WiFi's price is $30 per month with a one-year subscription.

Crowded public areas, such as airports, are common target areas of both mobile broadband technologies. However, the authors cannot say that one is better than the other. For those in need of a faster Internet connection, WiFi is a better solution; however, 3G is a better option for those desiring broader availability of Internet access. Due to the lack of roaming capability between 3G and WiFi networks, a mobile user is forced to choose one of the services. Therefore, there is a trade-off between throughput and the coverage area when a user chooses one of the two technologies.

In 2004, the City of Philadelphia announced to boost the city's economy by providing wireless Internet access throughout the city. Using street lights as WiFi access points, the city wanted to offer a low-cost (dial-up Internet access price, $20/month), ubiquitous broadband wireless connectivity to all points within the city [11]. The "Wireless Philadelphia" project would give a competitive advantage to the city of Philadelphia and reduce the city's telecommunication cost. In addition to that, it will also help to reduce the "digital divide", the gap between who can access to the Internet and those who can't. In effect it increases competition, through lower price points, with other wireless or wireline broadband providers, such as 3G, DSL, and/or Cable providers [8]. According to the wirelessphiladelphia.org, 15 square miles of Philadelphia is available for city wireless and it will be available throughout all 135 square miles by end of this year. After the city of Philadelphia, another big city, San Francisco, has launched an initiative to provide wireless access everywhere in the city. In San Francisco, Google proposed to provide free 300 Kbps service with advertising [2]. According to Daggett [3], hundreds of U.S. cities are currently debating strategies to develop citywide broadband networks, especially large cities – Philadelphia, San Francisco, Minneapolis, Boston, Houston, and Seattle. After establishing a city-wide wireless broadband network, 3G and WiFi provide wireless Internet service in the same area to the same target customers. The complimentary relationship between the two technologies will be changed into competitive relationship: 3G wireless carriers vs. municipal WiFi providers: who obtain the license from the city authorities. The following table is the summary of U.S. cities which have already started in the process of building city wireless network at the end of 2006.

[5] http://www.WiFinetnews.com

Table 2. Number of U.S. cities of Wireless Internet Access (Dec. 2006)

| CityWide/ Region | City Hotzone | Public Safety Only | Planned Deployment | Total |
|---|---|---|---|---|
| 79 | 48 | 36 | 149 | 312 |

* Source: www.municipalwireless.com

## 4. Competition Model and Equilibrium Analysis

A duopoly game model is a useful first approximation for the analysis of an industry with limited competition. Despite competition between 3G and WiFi technologies, the providers' cost structures and architectures of the same technology are similar for both. The authors assume that, as a rule, there will be equilibrium for both groups of providers. Thus, in a sense, this paper models two groups of providers whose members have approximately similar behaviors.

In this model, it is assumed that there are two service providers in the mobile broadband market without the possibility of new entrants. One is a CDMA-based 3G operator while the other is a WiFi based municipal wireless operator. Even if the mobile broadband services are not perfectly homogeneous, the authors can use a Bertrand price competition game model because the service can be a substitute for each other. Therefore, a rational user is not expected to buy both mobile broadband services at the same time.

The 3G cell size is determined by population density and geographic features. According to the Qualcomm's white paper [12], the radius of a 3G cell is 0.5 miles in the dense urban area, which means one 3G cell can cover 0.785 square miles. The area of the city of Philadelphia is 135 square miles and that of San Francisco is 46.7 square miles. Therefore, 172 3G cell sites are needed for the city of Philadelphia and 60 3G cell sites are needed for the city of San Francisco. For the WiFi coverage, approximately 700 WiFi hot-spots would be needed to cover the same area as one cellular base station [4]. The number of WiFi access points is determined by the 1:700 ratio, which means 120,400 access points are needed for the city of Philadelphia and 42,000 access points are needed for the city of San Francisco. The number of 3G cell sites and WiFi access points are included in infrastructure cost.

For the 3G provider, the authors assume that the provider has an existing infrastructure for the 2.5G wireless data service. The providers also have an advantage in using exiting base stations, which it could share the allotted spectrum band for its 2G voice service. The upgrade cost of a base station to 3G from 2.5G is expected to be about $250,000 [1]. For the WiFi provider, the equipment cost for the WiFi service is relatively low: $1,000 per access point. They also incur a monthly T1 Internet connection fee for every 'Hot Spot' ($300[6]). In the case of municipal wireless, using a city's traffic and light poles is a big advantage, which costs $36 annually on California [3]. Cities do not need to find a location for wireless access point and do not need to share revenue with a location owner. In summary, the annual cost of the WiFi provider is assumed to be approximately $4,600[7] per access point. There are other costs to operate a WiFi broadband network, including network operating center, billing, and marketing. However, in this model, the authors consider the WiFi access point and its connection to the Internet, which is equivalent to the 3G cellular network upgrading cost.

The following tables are survey data of the willingness-to-pay for WiFi Internet access and 3G Internet access. The authors borrowed these distributions from the 3G and WLAN market analysis papers [5], [10].

Table 3. Willingness-to-pay for WiFi & 3G

| WiFi Price | $20 | $40 | $60 | $80 |
|---|---|---|---|---|
| Subscriber (%) | 90% | 33% | 10% | 3% |
| **3G Price** | **$50** | **$60** | **$75** | **$100** |
| Subscriber (%) | 77% | 26% | 9% | 2% |

Based on the above willingness-to-pay distribution, authors estimate the demand curve using non-linear regression. The equation (1) is an estimate demand curve for 3G wireless Internet access service and the equation (2) is an estimate demand curve for WiFi Internet access service. These empirical data are much better fitted using a non-linear estimation than in a linear estimation. Comparing two demand curves, the demand curve for 3G wireless is more elastic than that for WiFi internet access, which means 3G customers would response more sensitively to price falling.

(1) $P_{3G} = 113.913*Q_{3G}^{-.192}$ ($R^2 = .999$, F=1423)

Where $P_{3G}$ = Price for 3G, $Q_{3G}$ = Market Penetration Rate for 3G Subscribers

(2) $P_{WF} = 73.678*e^{-.015*QWF}$ ($R^2 = .968$, F=60)

Where $P_{WF}$ = Price for WiFi, $Q_{WF}$ = Market Penetration Rate for WiFi Subscribers

The following figures represent the above two demand equations:

Figure 1. Demand Curve for 3G

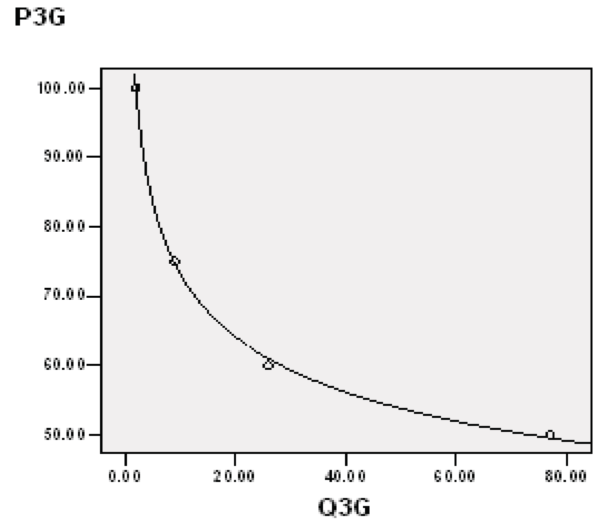
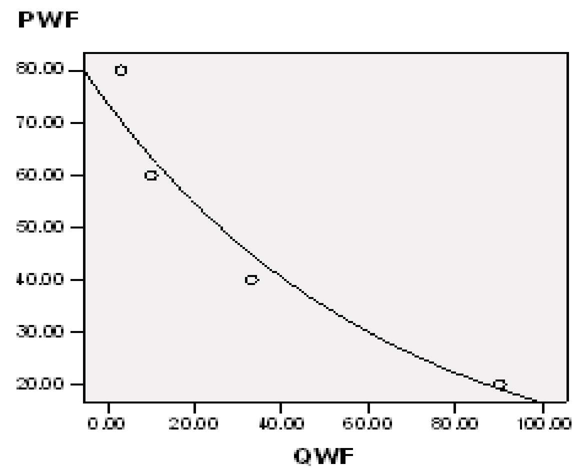



Figure 2. Demand Curve for WiFi




The authors assume that both providers use unlimited access pricing, which is prevalent pricing in the broadband wireless market. The authors set the minimum price of $20 for the Philadelphia case and $0 for the San Francisco case, given the suggested monthly price for both cities. In this model, pricing is the only variable to be decided by each provider.

The payoff functions of this model are defined as revenue minus cost (i.e., profit). The authors calculated profits based on annual revenue and cost. The revenue is defined by the number of subscribers times the monthly price of wireless Internet access service. The potential number of subscriber is limited by the population of each city even if both cities have a lot of visitors. The infrastructure cost is related with the number of 3G cell and WiFi access point. The following equations demonstrate profit functions of 3G ($Pf_{3G}$) and WiFi ($Pf_{WF}$) providers.

(3) $Pf_{3G} = P_{3G}*Q_{3G}*12$ months -{(Upgrade Cost to 3G)*(Number of Base Stations)}

[6] www.bandwidth.com.

[7] $4,600 = $1,000 + 12* $300

(4) $Pf_{WF} = P_{WF}*Q_{WF}*12$ months -{(Hot-Spot Building Cost)*(Number of Hot-Spots) + 12 months* (T1 Internet connection)}

Where $P_{3G} = 113.913*Q_{3G}^{-.192}$ and $P_{WF} = 73.678*e^{(-.015*Q_{WF})}$, $P_{3G} \geq 0$, $P_{WF}$ (Philadelphia) $\geq 20$, $P_{WF}(SF) \geq 0$.

The following table summarizes some parameter values in this model. Each city's population is used for the potential number of subscribers for both wireless Internet access services. The size of each city can be a basis to calculate a number of 3G cell sites and a number of WiFi access points. The suggested monthly price can give a minimum pricing range in each city.

Table 4. Some Parameter Values for Philadelphia Case and San Francisco Case

| | Philadelphia | San Francisco |
|---|---|---|
| Population (2000) | 1.5 millions | 776 thousands |
| Land Area | 135 sq. miles | 46.7 sq. miles |
| 3G Cell Site | 172 | 60 |
| WiFi Access Points | 120,400 | 42,000 |
| Suggested Monthly Pricing | $20 for Best Effort 1 M bps | Free for 300 Kbps |

Using equations (3) and (4) as profit functions, WiFi and 3G providers are assumed to try to find an optimal price level to maximize their payoff under the assumption that the competitor's price is constant. Since potential subscribers are forced to choose between the two wireless Internet access technologies, the total market shares of both technologies cannot go over 100%. Additionally, once each one goes to the equilibrium point, they cannot increase their profit by changing their price level. The following table summarizes the equilibrium outputs of both cases.

Table 5. Equilibrium Analysis Output

| | Philadelphia | San Francisco |
|---|---|---|
| Eq. Price {WiFi, 3G} | {$20, $48} | {$16, $47} |
| Eq. Market Share {WiFi, 3G} | {53%, 33%} | {67%, 33%} |
| Eq. Profits {WiFi, 3G} | {$18.8 B, $28.7 B* } | {$10.1 B, $14.4 B* } |

* B: billion

The equilibrium price of WiFi is lower than that of 3G in both cities. ($20 < $48 and $16 < $47) While the equilibrium market share of WiFi is higher than that of 3G (53% > 33% and 67% > 33%), the equilibrium profit of 3G is higher than that of WiFi ($18.8 B < $28.7B and $10.1 B < $14.4B). Therefore, in the near future, WiFi could potentially be the more popular of the two wireless Internet access methods while 3G carriers could enjoy higher profits by maintaining a high price strategy.

## 5. Conclusion

Wireless technology services offer competitive advantages through ever-evolving communication, receptiveness, and efficiency. The potential remains in 3G and WiFi, which are the two main wireless methods to access the Internet. Despite different origins, as 3G is a WAN-based cellular technology and WiFi is a LAN-based technology, the introduction of a municipal WiFi network can ignite competition within city boundaries. In this paper, the authors examine which technology is better positioned in the wireless broadband Internet access service market using a game theoretic model. In the equilibrium analysis, the authors found that WiFi could have a better market position in the future. However, by using a higher pricing strategy, the profit of 3G providers would be higher than that of WiFi providers. Finally, the municipal WiFi could be a useful public Internet access method and could become a strong competitor in this market with attractive low pricing.

## 6. References


[1] Bakhshi, S. K. (2001). 3G Infrastructure Vendor Profile: Nortel Networks, IDC Report.

[2] Daggett, B. (2006), Is Publicly Owned Information Infrastructure A Wise Public Investment for San Francisco?, retrieved January 1st, 2007 from http://www.media-alliance.org/images/sf-wireless-financial-report.pdf

[3] Daggett, B. (2007), Localizing the Internet: Five Ways Public Ownership Solves the U.S. Broadband Problem, retrieved March 1st, 2007 from http://www.newrules.org/info/5ways.pdf

[4] Dekleva, S., J. P. Shim, U. Varshney, and G. Knoerzer (2006). Evolution and Emerging Issues in Mobile Wireless Networks, Communications of the ACM, forthcoming.

[5] Henkel, D., N. Houchaime., N. Locatelli N., and S. Sigh S. (2002). The Impact of Emerging WLAN on Incumbent Cellular Service Providers in the U.S., retrieved January 1st, 2007 from http://www.mobilein.com/3GWLANFuture1.pdf

[6] Lehr, W. and McKnight L.W. (2003) Wireless Internet Access: 3G vs. WiFi?, Telecommunications Policy 27:351-370.

[7] Mossberg, W. (2006). Cingular Joins Rivals With Fast, Reliable Wireless Broadband, Wall Street Journal Jan. 19, 2006 Edition A9

[8] Scott, E. (2005), Wireless Philadelphia, Kennedy School of Government Case Program No. C14-05-1824.0

[9] Shim, J.P., U. Varshney, and S. Dekleva (2006). Wireless Evolution 2006: Cellular TV, Wearable

Computing, and RFID, Communications of the Association for Information Systems, Vol. 18, pp. 497-518.
[10] Strategic Policy Research (2001). 3G Wireless Market Assessment, retrieved January 1st, 2007 from http://www.spri.com/pdf/reports/news/SPR_3G_Sept_2001.pdf
[11] The Wireless Philadelphia Executive Committee (2005). Wireless Philadelphia Business Plan, retrieved January 1st, 2007 from http://www.phila.gov/wireless/pdfs/Wireless-Phila-Business-Plan-040305-1245pm.pdf
[12] Qualcomm (2004). 1xEV-DO White Paper, retrieved January 1st, 2007 from http://www.qualcomm.com/technology/1xev-do/published.html
[13] Wexler, J. (2006). 2006 Wireless LAN State-of-the-Market Report, retrieved January 1st, 2007 from http://www.webtorials.com/main/resource/papers/sotm/paper3/2006_WLAN.pdf