Testimony by:

Prof. S. Keshav
University of Waterloo, Waterloo, Ontario, Canada

At the hearing on:

Cell Phone Text Messaging Rate Increases and the State of Competition in the Wireless Market

held by the **Senate Subcommittee on Antitrust, Competition Policy and Consumer Rights**

June 16, 2009

The cost of text messaging

S. Keshav

Professor and Canada Research Chair in Tetherless Computing

School of Computer Science, University of Waterloo

Waterloo, Ontario, Canada N2L 3G1

June 10, 2009

1. Introduction

Text messaging, also known as Short Message Service or SMS, is a popular communications technology. Nearly 3.5 trillion text messages were sent worldwide according to Portio Research [1] and message volumes are expected to rise to five trillion messages worldwide in 2011. Over a trillion text messages were sent in the United States in 2008, according to the CTIA, a trade association [2].

Recently, most major US carriers raised the price of a text message sent by a consumer who is not subscribed to a text-messaging plan from 15 cents to 20 cents. Two questions naturally arise:

- What is the cost to a carrier to transmit a text message?
- Are these price increases cost-justified?

The purpose of this note is to address these questions.

I believe that to clearly analyze the costs incurred in text messaging and to form an informed opinion whether the price increases are cost-justified, it is necessary to understand the technological components which contribute to the cost of carrying a text message. These include the technologies for carrying text messages over wired and wireless links and the specialized databases for billing and locationing. By estimating the cost of each underlying component, I estimate the maxiumum possible cost to a carrier to carry a text message. It also allows me to determine whether increased message volumes should result in the increase in the cost of carrying a text message.

Here is a roadmap for the rest of the note: Section 2 describes the technology underlying text messaging. In Section 3, I use publicly-available information to estimate the cost of a text message as approximately 0.3 cents. Section 4 demonstrates that an increase in text messaging volume should not result in an increase in the cost per text message. Finally, Section 5 presents my conclusions.

2. An Overview of Text Messaging Technology

In order to understand the costs incurred in text messaging, I now present a brief overview of the underlying technology.

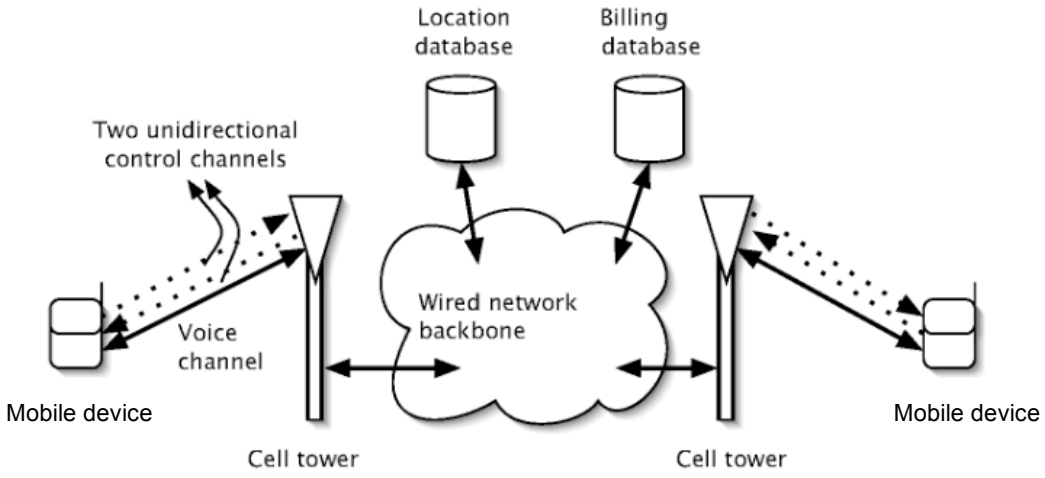

Figure 1: Text messaging components

Figure 1 shows an overview of the cellular phone system. It focuses on the path taken by a text message. Mobile devices receive wireless service from their associated cell towers. The cell towers are connected by wired links to a wired network backbone, which resembles the Internet backbone. This backbone is also connected to a location database, which keeps track of which cell tower is currently responsible for each mobile device, and a billing database, which keeps track of the messages sent and received by each mobile device.

Several wireless communication channels are maintained between a mobile device and its associated cell tower. When a voice call is in progress, a two-way voice channel between the cell tower and each mobile device is used to carry the call between the mobile device and the cell tower. In addition, a pair of one-way permanently-established control channels between the cell tower and each mobile device is used not only to establish and terminate voice calls but also to carry text messages.

A text message originating from a mobile device is sent over the air on a control channel to its associated cell tower, where it enters the network backbone. It is first stored in a message store associated with the source network (not shown), then routed to the destination cell tower, and then sent over another control channel to the destination mobile device. If the destination is not available at that time, the message is temporarily stored in a message store associated with the destination (not shown) and delivered when the destination becomes available.

A billing database keeps track of the messages sent and received by each mobile device. This database generates a monthly bill. Charges depend both on the usage as well as the plans to which the mobile device owners are subscribed. Finally, a location database keeps track of the current location of each mobile device.

3. The Cost of a Text Message

Telecommunications carriers do not disclose the cost of a text message publicly. Nevertheless, it is possible to estimate the cost of text messaging in two ways:

- A marginal price analysis allows a loose estimate of the maximum possible cost of a text message (Section 3.1)
- A careful consideration of the underlying technology allows tighter estimates (Sections 3.2-3.6)

3.1 Marginal Price Analysis

We can limit the maximum possible cost to the carrier of a text message by assuming that carriers do not want to lose money on their text-messaging service. For this to be true, their revenues--reflected in the price charged--must be larger than their costs. Specifically, the advertised price per text message must be the maximum possible cost of a text message.

Lets look at an example. According to its website, T Mobile offers a plan where up to 1000 messages can be sent for $9.99 [3]. With this plan, the price of a text message to a consumer is 1 cent. Assuming that T Mobile does not want to make a loss on this plan, this limits the maximum cost of a text message to 1 cent.

This analysis is simple but flawed. It assumes that a consumer who subscribes to, for example, a 400-message plan would actually send 400 messages over the course of a month. Consider a hypothetical carrier that discovered, through mesurements, that consumers who purchase 400-message plans sent only 200 messages on average. Such a carrier could allow a maximum of 400 messages in a plan, but price the plan assuming that only 200 messages would actually be sent. It would only incur costs for 200 messages. If we were to divide the price of the 400-message plan by 400, we would be over-estimating the cost of each message. We should be dividing by 200 instead. Another way of saying this is that we cannot discover the maximum cost of a text message simply by dividing the price of a plan by its maximum allowed volume: we need to estimate the *average* usage of a plan.

Although the average usage of a plan is a closely-guarded secret, we can estimate this value as follows. Consider a consumer who has a choice of a 400-message plan and an unlimited-message plan. Such a consumer would choose the unlimited message plan *only if they sent at least 400 messages on average every month*. Otherwise, they would be better off with the 400-message plan. This means that we can estimate the minimum average message volume for a plan as being equal to the maximum allowed message volume of the *next cheaper* plan. Continuing with our example, a consumer who chooses an unlimited-message plan has a strong incentive to send at least 400 messages a month. Therefore, if we divide the price of the unlimited-message plan by 400, we obtain a good estimate of the maximum possible cost of a text message.

As of June 5, 2009, T Mobile charges $15 for unlimited messages [3]. Its next lower tier has an upper limit of 1000 messages. So, the estimated maximum per-message cost for T Mobile is 1.5 cents. Similarly, AT&T charges $20 for unlimited messages [4] and the next lower tier has an

upper limit of 1500 messages. This gives us an estimated maximum message cost for AT&T of 1.33 cents. The equivalent maximum cost for Sprint is 2 cents [5]. Verizon appears to offer only per-message and unlimited message plans [6] and therefore it is not possible to estimate its cost using marginal price analysis.

These results are summarized in the table below.

Carrier	**Upper bound on cost of a text message (cents)**
T Mobile	1.5
AT&T	1.33
Sprint	2
Verizon	Cannot be determined using marginal price analysis.

Assuming that all carriers incur the same costs in carrying a text message, this analysis shows that the **cost of a text message is no more than 1.33 cents**.

3.2 Estimating the Cost of a Text Message from Consideration of Cellular Technology

We now refine our estimate of the cost of a text message by looking more closely at the underlying technology. A text message traverses two wireless and one wired path (see Figure 1). Typically, consumers pay both to send and to receive a text message. Therefore, we need to estimate only the cost of one wireless path and half of the wired path. We also need to estimate the cost of storing a text message if the recipient is unavailable. Finally, we need to estimate the costs of updating the billing and location databases. We now address these costs one by one.

3.2.1 Cost of the Wired Path

Portio Research estimates that roughly 3.5 trillion text messages were sent in 2008 [1]. We can express this in scientific notation as $3.5*10^{12}$ messages. The message volume for 3.5 trillion messages is $3.5*10^{12}$ messages * 140 bytes/message * 8 bits/byte = $3.92 * 10^{15}$ bits A high-capacity 10 Gigabit/second (Gbps) backbone network link carries 10^{10} bits/sec. To carry the entire global message volume for the entire year would therefore take $3.92 * 10^{15}$ bits/10^{10} bits/sec = $3.92 * 10^{5}$ seconds, which is about 62 hours, or about 4.5 days out of a total of 365 days in a year. Thus, carrying 3.5 trillion text messages imposes a load of only 1.24% on such a link, leaving 98.76% available for other traffic.

The wired network backbone of each carrier has many of these high-capacity links organized in the form of a mesh. No single link would carry the entire volume of text messages. Conservatively assuming that the link carrying the most text messaging traffic carries 20% of the entire messaging volume, this would imply that this link would have a text messaging load of 0.24% (leaving 99.76% available for other traffic).

Major carriers, such as Verizon, sell a nationwide10Gbps service to their customers [7]. Their own backbone links are likely to be of even higher capacity, and would therefore have

correspondingly lower loads. For instance, a 40 Gbps link, which is typical of a long-distance backbone link, would have a text messaging load of 0.06% (leaving 99.94% of the link available for other traffic). Other carriers are likely to have similar text message loads.

Given that the text messaging load, even under very conservative assumptions, does not exceed 0.06% (six ten-thousandths) of the capacity of a wired network link, we ignore the cost of the wired path in our calculations.

3.2.2 Cost of a Wireless Path

Unlike wired paths, which are very high capacity, wireless paths have significantly lower capacity. Moreover, spectrum licenses cost tens of billions of dollars. Therefore, the cost of a text message is primarily due to its use of a wireless path.

Text messages to and from a mobile device are sent over a pair of wireless control channels called the Random Access Channel (RACH) and the Standalone Dedicated Control Channel (SDCCH). These channels were originally designed for voice call control and signalling. As the volume of text-messaging volume grows, a carrier must allocate additional control channels to carry text messages: this displaces a Traffic Channel (TCH) that would otherwise be used for voice. We can use this fact to calculate the cost of a text message as follows.

Voice is typically carried in cellular networks at the rate of 8000 bits/second. A text message is 140 bytes or about 1100 bits. Therefore, a voice channel can carry about 7 text messages/second, or 420 text messages/minute. Of course, this assumes that a channel can be used at full capacity. However, the RACH uses a mode of transmission known as Slotted Aloha, whose capacity levels off at about 37% utilization. Therefore we can conservatively assume that the channel operates at only 20% utilization. This gives us the capacity of a channel as 84 text messages/minute.

The capacity of a channel decreases if messages can be lost and must be retransmitted. Studies show that the loss rate of text messages is about 3% [8]. Taking this into account, it can be shown that the resulting capacity of a channel, including the extra messages due to retransmissions, is about 81 messages/minute.

The price of a voice minute in the US and Canada is about 15 cents/minute when billed as *overage* (that is, over the plan limit) but is only about 7 cents/minute as part of a plan, depending on the carrier [9]. The per-minute cost of a channel is upper-bounded by this price. So, the wireless path cost of a text message in the US cannot exceed roughly 7c/81 ~= 0.09 cents in the US and about 0.10 cents in Canada.

3.2.3 Billing Cost

As shown in Figure 1, in addition to the cost of the channel, each text message can result in one or more control messages being sent to a billing system. These messages are used to provide the billing system with the identity of the sender and the receiver of the text message, so that their monthly bills can be properly calculated. Specifically, these messages are used for monitoring

usage, finding what rate plan a message should be charged at, and then adding this charge to the sender's and the receiver's bill.

One way to estimate the cost of these control messages is based on the fact that that carriers are certainly not going to make a loss when pricing a text message as part of a plan at 1.33 cents/text message (Section 3.1). Based on the computation that the wireless path cost is roughly 0.1 cents (Section 3.2.2), the additional cost of billing cannot exceed 1.23 cents/text message. If this is indeed the cost of billing, carriers would make no profit on a text message as part of a plan but a profit of 13.6-18.6 cents/text message for out-of-plan messages (which are charged at between 15 and 20 cents a text message).

However, it seems implausible that accounting for a text message would cost twelve times as much as carrying the message itself. If we assume that accounting is *twice* as expensive as carrying the message (a conservative estimate) then we can estimate the cost of a text message, including billing at 0.3 cents/text message.

3.2.4 Paging Cost

If the carrier's mobile device location database, called the Location Register in Figure 1, does not know the current location (i.e. nearest cell tower) of a mobile device, a special control channel called the paging channel is used to locate it. Essentially, a *paging* message is sent to all the cell towers where a mobile device could be located, based on its recent mobility history, and the mobile device answers the paging message making itself known. The recipient of a text message, therefore, causes a paging message load on the operator which adds to the operator's cost.

The calculations thus far do not include the paging cost incurred by a text message. Paging costs depend on the choice of *paging policy*, that is, how aggressively the location of a mobile device is tracked. With an aggressive paging policy, every movement of a mobile device to a new cell tower location results in an update to the Location Register, but then there is no need for additional paging messages to locate the mobile device when it receives a text message. This works well for relatively static mobile devices that will not result in the generation of too many location update messages. With less-aggressive location tracking, all cell towers near the last known cell tower need to be paged. This reduces the tracking costs for highly mobile phones, but increases paging costs. How should this be accounted for?

Note that paging traffic is necessary even for establishing a standard voice call. Therefore, as a first cut approximation, it is reasonable to assume that the cost of a voice minute already includes the cost of paging. Because the wireless path cost of a text message was computed from the cost of a voice minute (Section 3.2.1), the paging cost of a text message is included in the estimate of 0.1 cents/text message.

One could argue that this estimate is too low because a voice call that lasts, on average, three minutes, and requires only one page, but each text message may require its own page. So, the costs of paging could be proportionately higher for text messages because they have a much shorter duration. However, once a mobile has been located, either for a voice call or an text message, it no longer needs to be paged again, because its location is known. If a mobile were to

receive three text messages over the course of three minutes, for example, only the first text message would incur a paging cost, just as a voice call would. The paging costs for a call or a text message are comparable, and the analysis of Section 3.2.1 continues to hold.

3.2.5 Storage Cost

All text messages are stored at a message storage system associated with the source. Moreover, if a text message cannot be delivered to a recipient, it must be stored until the recipient becomes available. A carrier has to pay for a message storage system, which adds to the cost of delivering each temporarily-stored message. The cost of a storage system depends on its capacity: the higher the capacity, the greater the cost.

Today, consumers can buy 5 Terabyte of storage, which is enough to store 35.5 million text messages, for about $1000 [10]. More reliable storage systems with support for high performance and fault tolerance using RAID technology are a little more expensive, and cost about $1000/Terabyte [11].

We can estimate the approximate cost of storage as follows. Suppose that all text messages are stored either at the source or the destination, on average, for one day (this is a very conservative assumption: most text messages are delivered within a minute or two). In 2008, 3.5 trillion text messages were sent, which is roughly 9.58 billion messages per day. If each message were stored for one day, then we would need storage for 9.58 billion messages. This requires roughly 1,343 Terabytes, which costs around $1.34 million. This adds a storage cost of only 0.00014 cents to each text message.

3.2.6 Database Cost

Carriers need to pay for a location database, usually called a Home Location Register, and a billing database. These systems can be quite expensive. For instance, a high-end database from Oracle Corp. can cost up to a million US dollars [12]. It is reasonable to assume that a location register database has a similar cost. Conservatively, the total database cost to a high-end carrier is very unlikely to exceed $10,000,000 per year. Such a carrier would carry at least 1% of the total global text-messaging traffic, or about 35 billion text messages. This would add a per-message database cost of 100 cents/dollar*10*10^6dollars/35*10^9cents/message = 0.03 cents/message. Again, this is a negligible cost.

3.2.7 Summary

Including the cost of the wired and wireless paths, billing, paging, databases, and storage, the cost of a text message is likely to be no greater than 0.3 cents**.**

4. Does the increase in text messaging volumes increase the cost of each message?

Increased text message volumes do increase the total cost to an operator, but the cost *per message* does not appreciably change. Indeed, they tend to decline per message. This is because fixed costs are amortized over larger numbers of messages, and per-message variable costs, which we have discussed above, do not change with the number of messages carried.

The only possible reason why overall costs may go up with increased volume of messages is if a carrier runs out of spectrum resources and is therefore unable to carry voice calls. This introduces a 'congestion cost.'

It is unlikely that a carrier would run out of spectrum from carrying text messages. Each cell tower typically has three 'sectors' which can each handle approximately 1000 voice calls simultaneously. This would allow the spectrum available at a single sector at a single cell phone tower to handle 81,000 text messages a minute, and a single cell phone tower to handle 243,000 text messages a minute, or roughly 128 billion text messages a year. So, the entire international text messaging volume in 2008 could be handled by just 280 cell towers. Compare this to the total number of cell towers in the world which are estimated to be around 4 million, with 300,000 sold in 2008 alone [13].

Of course, this is a simplistic calculation, but it merely points out that radio spectrum, though scarce, is not overly used by text messages. Therefore, even with increased text messaging volumes, the underlying costs do not increase.

5. Conclusions

I have demonstrated using publicly available data that the maximum cost of a text message is very unlikely to exceed 0.3 cents. I now address the issue of whether the price of text messages is commensurate with this cost.

Carriers typically charge consumers 15-20 cents/text message for non-plan messages and about 1.5 cents/text message for in-plan messages. Therefore, carriers have a profit margin of at least 80% for in-plan messages and at least 98% for non-plan messages. Typical profit margins in the software industry are around 40% and typical profit margins in regulated monopolies are in the range of 5-10%. The profit margins enjoyed by carriers of text messages greatly exceed these guidelines.

Major US carriers recently raised the price of non-plan messages from 15 to 20 cents. No reason was given for this increase other than a reference to increasing messaging volumes. As the preceding analysis shows, one should see the cost per message actually decrease as a function of text messaging volumes. Therefore, it is my opinion that the price increases are not cost-justified.

References

[1] Mobile Messaging Futures 2009-2013, Portio Research, November 2008**.** http://www.portioresearch.com/MMF09-13.html

[2] CTIA – The Wireless Association® Announces Semi-Annual Wireless Industry Survey Results, April 2009. http://www.ctia.org/media/press/body.cfm/prid/1811

[3] T-Mobile Text Messaging Plans

http://www.t-mobile.com/shop/addons/Services/information.aspx?PAsset=Messaging&oscid=4CD51BA7-B5AF-4AB2-85E0-50EC0AF141F9&tp=Svc_Tab_TextMessaging

[4] AT&T Text Messaging Plans

http://www.wireless.att.com/cell-phone-service/services/services-list.jsp?catId=cat1470003&LOSGId=&catName=Messaging+and+MEdia(TM)+Bundles&_requestid=278648

[5] V. McCann, Letter to Senator H. Kohl in response to his enquiry, October 6, 2008.

[6] Verizon consumer plans. http://www.verizonwireless.com/b2c/splash/plansingleline.jsp?lid=//global//plans//voice+plans//individual

[7] Verizon Nationwide 10 Gbps service. http://www22.verizon.com/wholesale/solutions/solution/U.S.%2BWavelength.html

[8] Earl Oliver, Exploiting the Short Message Service as a Control Channel in Challenged Network Environments. *MobiCom 2008 Workshop on Challenged Networks (CHANTS*). San Francisco, United States. September 2008.

[9] The mean cost per voice minute in 2007 was 11 cents in Canada and 6 cents/minute in the US. The global high was 32 cents a minute in Switzerland and low was 2 cents a minute in Bangladesh and India.

[10] LaCie 5big Network 5TB drive. http://www.cdw.com/shop/products/default.aspx?EDC=1596257

[11] AmazonS3 costs. http://aws.amazon.com/s3/faqs/#How_much_does_Amazon_S3_cost

[12] Oracle Enterprise Database Price List. http://www.oracle.com/corporate/pricing/technology-price-list.pdf

[13] Cell Tower Statistics. http://www.instat.com/press.asp?ID=1069&sku=IN0401275GW