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Washington, DC 20554

In the Matter of	)	
	)	
Facilitating the Deployment of	)	PS Docket No. 11-153
Text-to-911 and Other Next Generation	)	
911 Applications	)	
	)	
Framework for Next Generation	)	PS Docket No. 10-255
911 Deployment	)	

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Testing the Reliability, Latency and Delivery Sequence of SMS Messages in a 9-1-1 Environment

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Over the last decade, the use of Short Message Service (SMS) messaging as a prevalent means of communicating has increased significantly, particularly among younger users and persons with disabilities. Conversely, currently, the only means of reaching emergency assistance through a public safety answering point (PSAP) is by making a voice call. In light of the public's increased use of alternate forms of communication, the 9-1-1 Industry is investigating additional methods of requesting assistance and contacting 9-1-1. One such method being investigated is SMS messaging.

Most people are familiar with SMS only as a way for one mobile user to communicate with another. This type of messaging is typically referred to in the industry as peer–to-peer messaging. Those who use peer-to-peer SMS messaging have likely experienced situations where their messages were delayed, delivered out-of-sequence or, in some cases, never delivered to the recipient. Some who are evaluating the use of SMS as a means to contact 9-1-1 conclude that these experiences automatically preclude the use of SMS messaging for 9-1-1 communications.

However, peer-to-peer messaging is not the only form of SMS messaging that has been deployed in the industry. SMS messaging is also used for over the air activation and programming of mobile devices, alarm systems, remote telematics, peer-to-application and application-to-peer messaging. Over the years, protocols, standards and techniques have been developed to support the many different uses of SMS. Many of these non peer–to-peer forms of SMS messaging employ different delivery functionality. This short study explores an alternate message flow, which we will call the 9-1-1 Message Center. This proposed alternative message flow is a potential way to add reliability and timely delivery of 9-1-1 SMS messages to and from a PSAP. This flow is already supported in the SMS infrastructure, implementations and standards today.

In this study tens of thousands of actual SMS messages were sent from a simulated PSAP to a mobile device and from a mobile device to the simulated PSAP, using the 9-1-1 Message Center. In these tests, the latency and delivery characteristics were measured to determine if SMS is suitable for timely and reliable communications with 9-1-1.

Peer-to-Peer Architecture:

Most SMS messaging that people are familiar with is peer-to-peer messaging. In this type of messaging, one mobile user sends an SMS message to another mobile user.

Peer-to-Peer SMS Messaging

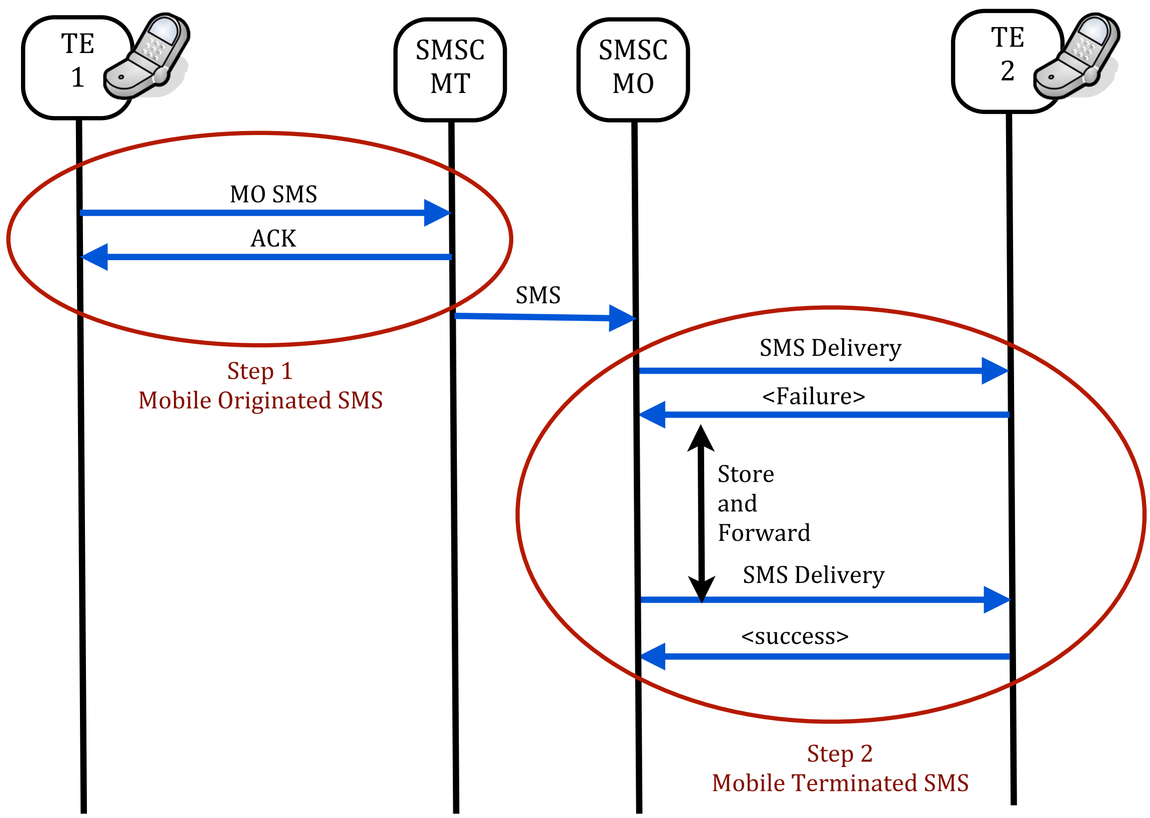

Figure 1: Call Flow of Peer-to-Peer Messaging

Typically the messaging delivery times in peer-to-peer messaging is relatively fast, but by design, the messages can be delayed due to queueing used for network capacity management. Peer-to-peer messaging is made up of two steps. The first step is the initial mobile originated (MO) SMS message from the initiating mobile (TE 1) to its associated Short Message Service Center (SMSC). The second step is the mobile termination (MT) delivery of the SMS message to the target mobile (TE 2).

In the first step, the mobile (TE 1) sends a SMS message to a destination. The mobile sends that message through its serving MSC, to the home SMSC assigned to the phone. Once the home SMSC successfully receives this MO SMS message, it will acknowledge back to the mobile that it has received the message. Once the mobile receives this acknowledgement, it will indicate to the user that the SMS message has been sent. This is a relatively quick process and, if successful, occurs within several seconds. There is no store and forwarding of messages in this step and the message will either make it to the SMSC or it will fail with an indication to the user.

The second step is the actual delivery of the SMS message to the recipient. The Mobile Terminated SMSC (MT SMSC) will first check to see if the mobile is turned on and to which MSC the mobile is attached. Once the SMSC knows the serving MSC, it will attempt to deliver the SMS message to the target mobile through the serving MSC. If the mobile is not turned on or the message delivery fails, the MT SMSC will place the SMS message into a queue for later delivery. The length of time that the message will be placed into the queue will be dependent on configuration parameters in the queue such as retry intervals, time of day, nature of message delivery failure, class of user, traffic on the system, etc. Periodically the MT SMSC will attempt to deliver the message again. This will continue until the message is delivered or until the validity timer of the message expires and the message is discarded.

The delays and discarded messages that occur in peer-to-peer messaging is not a failure of SMS messaging, but rather a network design implemented to address the tremendous volume of messages.

Alternate messaging to support SMS to 9-1-1

SMS messaging in a 9-1-1 environment requires a higher level of reliability and a lower latency than SMS messaging in a commercial or peer-to-peer environment. A higher level of reliability and lower overall latency of the delivery of the SMS messages can be accomplished without changing the SMS network, but rather by using different queues and retry mechanisms. These operational changes will be referred to here as the "9-1-1 Message Center."

The 9-1-1 Message Center (9-1-1 SMSC) is not a new element but rather a new operational use of an existing element. It uses existing wireless SMS standards to manage the delivery of SMS messages between the 9-1-1 PSAP and the emergency texter.

The initial delivery of the MO SMS message from the mobile to the PSAP is very reliable without change. It is the same mechanism that is used in Step 1 of the peer-to-peer call flow. As is also true with peer-to-peer messaging, there is no store and forward mechanism involved in the sending of the mobile originated SMS message from the initiating mobile to the SMSC (same as Step 1 of peer-to-peer). Because of this, the main part of the 9-1-1 SMSC architecture focuses on the delivery of the SMS message from the PSAP to the text initiator.

9-1-1 SMSC Concept

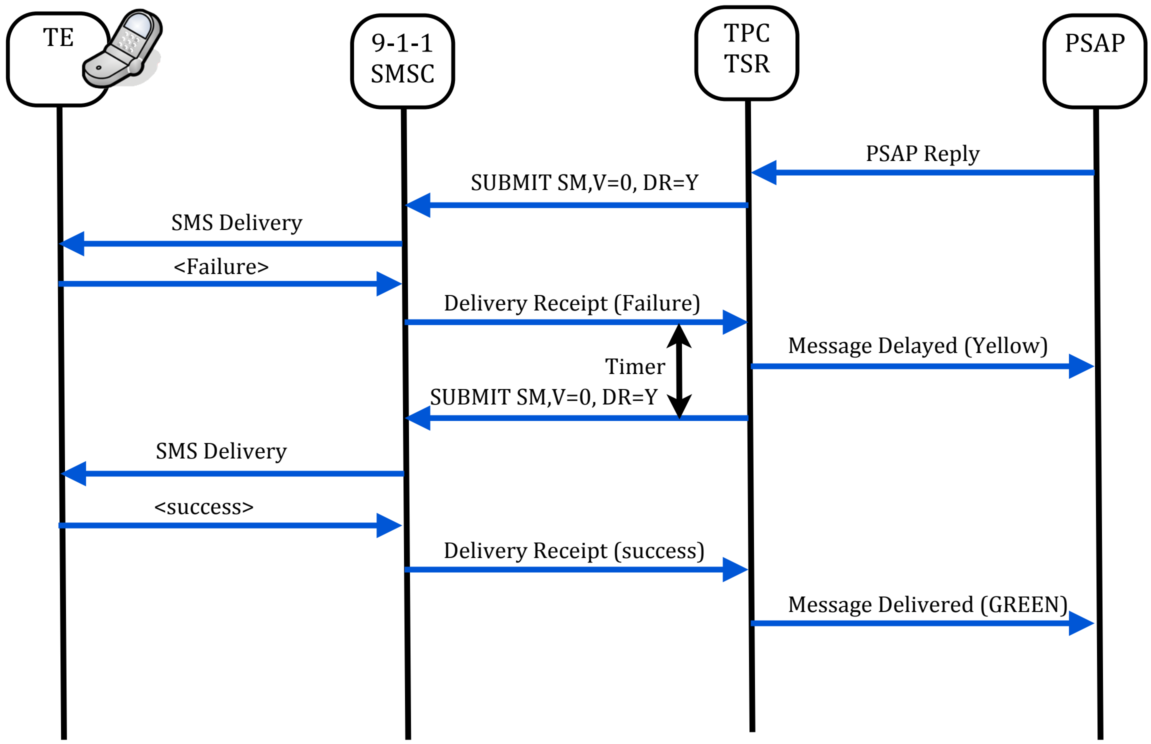

Figure 2 : 9-1-1 SMSC Call Flow

With the 9-1-1 SMSC, the PSAP first initiates a reply back to the text initiator through the Text Selective Router (TSR) and the Text Positioning Center (TPC). The TPC talks to the 9-1-1 SMSC over existing standard SMPP V3.4 links. In the message to the 9-1-1 SMSC, the TPC indicates that if the message delivery fails on the first attempt, it should not be retried. This is accomplished by the TPC setting the validity timer to 0 in the message it sends to the 9-1-1 SMSC. The TPC also requests status of the delivery success or failure of the message to the mobile by asking for end-to-end delivery receipts.

When the 9-1-1 SMSC receives this message from the TPC, it will determine the serving MSC of the mobile and attempt to deliver the message to the mobile. If a failure occurs, the 9-1-1 SMSC will know by the failure message returned from the MSC or Home Location Register (HLR) or the lack of a response. Because the TPC set the validity period to 0, the 9-1-1 SMSC will discard the message rather than store and forward it for later delivery. Also because delivery receipts were requested, the 9-1-1 SMSC will return a delivery receipt to the TPC indicating that the message was not delivered. The TPC will then be able to notify the PSAP that the message has been delayed and attempt to have the message resent under its own 9-1-1 specific retry schedule.

After a short definable delay of a several seconds, the TPC will again ask the 9-1-1 SMSC to redeliver the same message. The entire control of the delivery of the message is under the TPC. Again, the 9-1-1 SMSC will attempt delivery of the message to the mobile. If the delivery is a success, the 9-1-1 SMSC will send a delivery receipt back to the TPC indicating that the message was successfully delivered. The PSAP will then also be notified that the message was delivered.

The biggest difference here between the 9-1-1 SMSC and peer-to-peer messaging is that with the 9-1-1 SMSC, the delivery of the messages to the texter from the PSAP is managed outside of the SMSC so that reliability, low latency and in-sequence delivery can be optimized for 9-1-1 needs. In peer-to-peer messaging, the delivery mechanism are built around the idea of managing peaks of traffic involving billions of SMS messages and the retry mechanisms are outside the view of the external elements.

Because the TPC is managing the delivery of the messages through the 9-1-1 SMSC, the TPC can ensure that messages are delivered in order. This delivery management ensures that no out-of-sequence messages will be delivered to the mobile.

Alignment with NENA i3

The logical elements of the 9-1-1 SMSC, TPC and TSR are described in this paper as generic terms to illustrate the flows of SMS messages in terms that are parallel to the existing wireless voice elements of the MPC (Mobile Positioning Center) and SR (Selective Router). These nodes do map very nicely to the NENA i3 model, and as those elements are further defined in standards, it is envisioned that these elements will evolve to the NENA i3 elements. The Text Positioning Center (TPC) is analogous to the NENA i3 Legacy Network Gateway (LNG) and the Text Selective Router (TSR) is analogous to the NENA i3 Emergency Services Routing Proxy (ESRP).

Test Setup:

All the testing of SMS delays published, to date, have only involved peer-to-peer messaging. A testing environment was needed to evaluate the operational characteristics of the use of SMS messaging where the 9-1-1 SMSC functionality was employed.

The following test environment was configured to validate the 9-1-1 SMSC concept using commercially available and operationally deployed wireless components.

1. Message Generator – (PSAP side) - A Message Generator (MG) application was developed that simulates the retry and management functionality of the Text Positioning Center (TPC) and PSAP components. The MG application connects to the SMSC over a VPN and uses standard SMPP V3.4 messaging to talk to a standard Nokia Siemens SMSC.

2. SMS Probe – (Mobile Phone Side) - A custom hardware device was developed to receive the SMS messages and measure the delay. The device is made up of a Telit GSM or CDMA cell phone module, a GPS for timing and location, a microprocessor for overall automated processing and a SD memory card for data storage.

Figure 3: SMS Probe Unit

3. Home Network – The home network is only providing GSM HLR and GSM SMSC services. The SMS Probe will be roaming into the carrier network where the delivery will be tested. This allows the device to work in any GSM

carrier's network across the U.S. For this test, a small GSM carrier's HLR and SMSC were used. This uses exactly the same network element that would be used if the 9-1-1 SMSC was provided as a stand alone or 3rd party hosted node. It also works exactly the same if the home network elements were located within the Serving Network. The measurable delay characteristics and congestion issues occur within the Serving Network.

4. Serving Network – The serving network will be providing MSC and cell services and will actually be delivering the SMS messages. For this testing, two of the major national GSM carriers were used to deliver the messages to the SMS Probe. The Probes roamed into these serving networks.

Test Setup

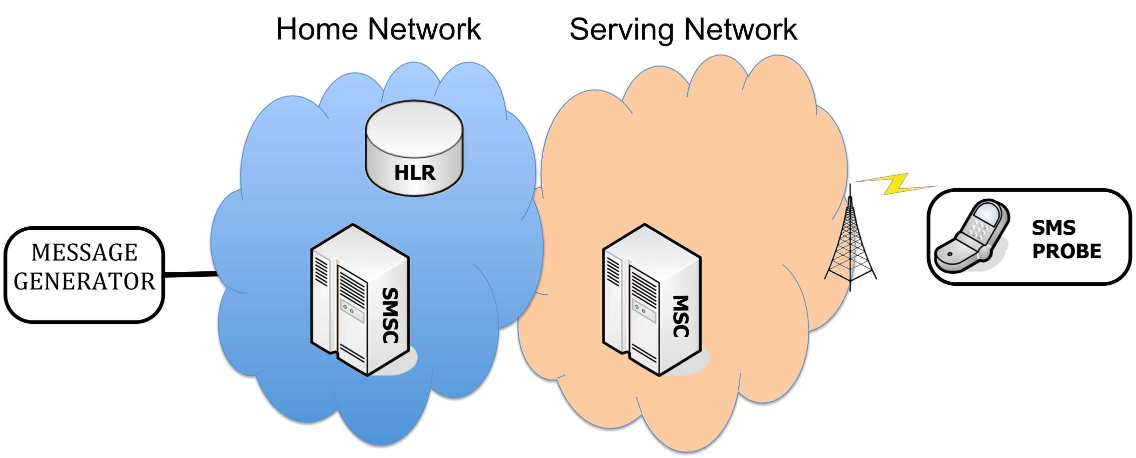

Figure 4: Test Setup Network Connectivity

The MG is connected to the home SMSC over a VPN connection. It is communicating with the SMSC using standard SMPP V3.4. The MG is configured so that it sends a series of SMS messages from the MG through the 9-1-1 SMSC in the home network and then through the MSC and cell site in the serving network to the SMS Probe. The SMS Probe can then measure the latency, reliability and out-of-sequence delivery of the SMS messages. Additionally, the SMS Probe can initiate MO SMS messages back through the serving network to the home network SMSC and then(?) back to the MG so that the MG can measure the reverse latency, reliability and out–of-sequence delivery.

The SMS message that is sent from the MG is made up of the following data elements:

AA,BB,CC,DD,EE,FF,GG

AA	The month that the SMS message was sent.
BB	The day of the month that the SMS message was sent.
CC	The year that the SMS message was sent.

DD Time in seconds since midnight (GMT) that the initial attempt of the message was sent.
EE Time in seconds since midnight (GMT) that this attempt of the message was sent.
FF Message sequence number.
GG Message attempt number.

The MG will send the first message to the 9-1-1 SMSC. The MG will set the validity period in the SMPP message to "0" and will ask for delivery receipts. The SMSC will then attempt to deliver the SMS message to the SMS Probe. It will query the home HLR to determine the serving MSC. The SMSC will then deliver the message to the MSC which will then deliver the SMS message to the SMS probe. If the SMS message is successfully delivered to the mobile, the SMSC will send back a delivery receipt of "Delivered." The MG will then wait 20 seconds and will then send the next message in the sequence.

If the message is not delivered, the SMSC will return back an error message, indicating why the message was not delivered. Also since the validity period was set at "0", the SMSC discards the message rather than store it for later delivery. When the MG receives this error, it will increment the "message attempt" number by one and send a new SMS message to the SMSC after a 4 second pause. It will continue doing this until the message is delivered or the maximum retry counter is exceeded.

When the SMS Probe receives the SMS message from the MG, it will log it to the SD card (onboard data storage card) along with the current GPS time, GPS X/Y location and ground speed. Along with this GPS information, the SMS Probe will also log the current cellular radio environment conditions at the time the SMS was received. This information includes Carrier, Base Station ID, RX Quality, Timing Advance (indicator of distance from cell site) and Received Signal Strength Indication.

With the combination of the time stamp data and sequence information sent by the MG and the GPS and RF data captured by the SMS Probe, the following data can be determined under differing environments:

1) SMS Latency – The time it takes to deliver an SMS message to a mobile using the 9-1-1 message center concept.
2) Retry – Frequency and number of retries necessary to deliver an SMS message.
3) Retry Latency – The delay introduced when an SMS message must be retried.
4) Message Loss – Any messages that are reported as delivered but not received by the SMS probe.
5) Out-of-sequence delivery – Any messages that are delivered out of sequence from the perspective of the MG.

Applicability of Test Environment to Real World Implementations

The test environment fully tests the functionality, reliability and delay characteristics of the 9-1-1 SMSC even though the 9-1-1 SMSC is in the Home Network while the SMS Probe is in the Serving Network. This is true because of how SMS works. With mobile terminated SMS messages, as discussed above, the SMSC will first contact the HLR to determine which MSC the mobile is being served by. It does not matter if this MSC is in the home market or a roaming market. The SMSC will treat the messaging exactly the same. Once the SMSC has the serving MSC, it will then send the SMS message directly to that MSC to de delivered to the SMS Probe. For subsequent SMS messages to that same mobile, typically most SMSCs will cache that MSC location so they do not have to go back to the HLR for each message unless they get a error message from the MSC indicating that the mobile is no longer attached to the MSC and has moved to a different MSC.

For mobile terminated SMS messages, there can be as many SMSCs in the network as the carriers need. Typically carriers may have different SMSCs in the network for different functions such as peer-to-peer messaging, over the air programming and activations and machine-to-machine communications to name just a few. The 9-1-1 SMSC fits into the network in the same way.

If the 9-1-1 SMSC had been placed into the serving network, the results would have been identical or possibly a little faster due to less distance in the connecting networks. The testing environment used here FULLY tests the delivery functionality of the 9-1-1 SMSC and the delay characteristics of the serving network. For these tests the serving networks were two of the major US nation-wide GSM carriers. This allowed the delivery of messages under real world, high traffic environments. While these test were only done on GSM networks, CDMA networks also send SMS messages in very similar manner to GSM. It would be expected that with CDMA, the reliability would be the same and the only differences would be small differences in timing of the delivery of the SMS messages over the air interface.

Errors Introduced:

With the test environment, the precision of the timing measurement is only to the second. The MG will always send out its SMS message to the SMS Probe at the beginning of the second, but when the SMS Probe receives the SMS message, it will log the time to the last whole second. Therefore, the time reported for the latency of the delivery of the SMS could be up to 1 second less than the actual time. Also, when messages are retried, a delay of 4 seconds is added by the MG. This is a configurable timer, but it is not an additional delay added by the wireless network.

Test Environments:

SMS messages were sent to the SMS Probe in various locations, mobility situations and signal strengths. The following are the different scenarios under which Mobile Terminated Messages were sent.

Mobile Terminated Scenario 1:

The SMS Probe was located near the University of Colorado Football Stadium during the November 4, 2011, ESPN televised game. The messages were sent throughout the game and after the game. 1001 SMS messages were sent with a delay of 20 seconds between messages and the retry interval between any retransmitted messages was 4 seconds. The total duration between the messages was about 24 seconds with the delivery delay.

Mobile Terminated Scenarios 2, 3 and 4:

The SMS Probe was located at the same location as Scenario 1, but the measurements were made throughout the weekend. The duration between the messages was 20 seconds and the retry interval for any retransmitted messages was 4 seconds.

Mobile Terminated Scenario 5:

The SMS Probe was located in a residential neighborhood in Columbia, SC. The structure was a single story brick structure. The duration between the messages was 20 seconds and the retry interval for any retransmitted messages was 4 seconds.

Mobile Terminated Scenario 6:

The SMS Probe was located in a residential neighborhood in Westminster, CO. The structure was a single story wood structure. The duration between the messages was 20 seconds and the retry interval for any retransmitted messages was 4 seconds. 16dB of attenuation was added to the antenna to simulate a low signal area. Voice quality on the device was poor under these conditions.

Mobile Terminated Scenario 7:

The SMS Probe was located on the 5th floor of a hotel in downtown San Diego near the convention center. The probe was located on the window sill to allow reception of the GPS signal. The duration between the messages was 20 seconds and the retry interval for any retransmitted messages was 4 seconds.

Mobile Terminated Scenario 8:

The SMS Probe was located in a car and driven from Westminster, CO to Boulder, CO and back. The probe was also stationary in Boulder for several hours. The duration between the messages was 20 seconds and the retry interval for any retransmitted messages was 4 seconds.

Mobile Terminated Scenario 9:

The SMS Probe was located outside in an office park near Highway 287 in Lewisville, CO. This is an area of low RF signal. From this same location, voice call quality was poor. The duration between the messages was 20 seconds and the retry interval for any retransmitted messages was 4 seconds.

Mobile Terminated Scenario 10:

In this scenario, the SMS Probe was driven from Westminster, CO to Boulder, CO and then to Denver, CO. The duration between the messages was 20 seconds and the retry interval for any retransmitted messages was 4 seconds.

Mobile Terminated Scenario 11:

The SMS Probe was located in an urban area of downtown San Jose, CA. The duration between the messages was 20 seconds and the retry interval for any retransmitted messages was 4 seconds.

Mobile Terminated Scenario 12:

The SMS Probe was located in downtown Denver near several highways. The duration between the messages was 20 seconds and the retry interval for any retransmitted messages was 4 seconds.

Mobile Terminated Scenario 13:

The SMS Probe was located in the basement of an office complex in Longmont, CO. The area had low cell coverage and was not able to consistently hold a voice call. 6db of attenuation was then added to the antenna. The duration between the messages was 10 seconds and the retry interval for any retransmitted messages was 4 seconds.

Mobile Terminated Scenario 14:

The SMS Probe was located in a residential area in Denver, CO. The duration between the messages was 20 seconds and the retry interval for any retransmitted messages was 4 seconds.

Mobile Terminated Scenario 15:

The SMS Probe was located on the 7th floor of a hotel near 16th Street NW and O Street in Washington, D.C. The duration between the messages was 10 seconds and the retry interval for any retransmitted messages was 4 seconds.

Mobile Terminated Scenarios 16 & 17:

In these two scenarios, the SMS Probe was located in the same location, but messages were carried on different carrier networks (Carrier A for scenario 16 and Carrier B for scenario 17). The SMS Probe was located within a metal aircraft hangar on the grounds of an airport. 10dB of attenuation was added. Without the attenuation, standard phones on both carriers had spotty voice service. The duration between the messages was 10 seconds and the retry interval for any retransmitted messages was 4 seconds.

Mobile Originated Scenario 1:

The SMS Probe originated SMS Messages in Westminster, CO, Longmont, CO, Washington, D.C., and the airport hangar location. The duration between the messages was 20 seconds and the retry interval for any retransmitted messages was 4 seconds.

Test Data:

A total of 31, 868 SMS messages were sent from the MG to the SMS Probe under different environments, times and carriers to obtain a statistically significant number of samples under varying conditions. In addition to the Mobile Terminated SMS Messages, 700 Mobile Originated SMS messages were sent from the SMS Probe to the MG. For each of the above testing scenarios, the following values were calculated.

1) Number of SMS messages sent – This the total number of SMS messages that were sent in this scenario. This included all messages sent whether receipt was successful or not. It does not include retransmitted messages as they are considered part of the original message.
2) Number of messages lost – This is the count of total messages sent by the MG minus the total number of messages received by the SMS Probe.
3) Number of out-of-sequence messages – This is the total number of messages received by the SMS probe where they did not arrive in sequential order based upon the sequence number sent by the MG.

4) Median of SMS latency – This is the median of the sample data of #1 of the latency of the SMS messages. The latency is measured as the difference in seconds of the time the initial message was sent and marked by the MG to the time the first successful message was received by the SMS Probe. For retransmitted messages, this would be the time the retransmitted message was received.
5) Maximum SMS latency – This is the maximum latency that was measured by the SMS Probe for a specific SMS message within the entire scenario data set. This time will include the time of the initial SMS message and any necessary retransmissions, along with the MG introduced delays between messages.
6) Percent of messages delivered in 0-4 seconds – The percentage of the messages in the data set that had a latency measured as being between 0 and 4 seconds.
7) Percent of messages delivered in 5-10 seconds – The percentage of the messages in the data set that had a latency measured as being between 5 and 10 seconds.
8) Percent of messages delivered in 11-20seconds – The percentage of the messages in the data set that had a latency measured as being between 11 and 20 seconds.
9) Percent of messages delivered in 21-60 seconds – The percentage of the messages in the data set that had a latency measured as being between 21 and 60 seconds.
10) Percent of messages delivered in 61-90 seconds – The percentage of the messages in the data set that had a latency measured as being between 61 and 90 seconds.
11) Percent of messages delivered in > 90 seconds – The percentage of the messages in the data set that had a latency of greater than 90 seconds.
12) Standard deviation of latency –The standard deviation of the above latency data set.
13) 67% of messages delivered within – This is the number of seconds that 67% of all of the messages in this scenario were delivered to the SMS probe. This would include any added time for necessary retransmissions. This data point was derived by plotting the cumulative distribution of the latency of the SMS messages.
14) 90% of messages delivered within – This is the number of seconds that 90% of all of the messages in this scenario were delivered to the SMS probe. This would include any added time for necessary retransmissions. This data point was derived by plotting the cumulative distribution of the latency of the SMS messages.
15) 99% of messages delivered within – This is the number of seconds that 99% of all of the messages in this scenario were delivered to the SMS probe. This would include any added time for necessary retransmissions. This data point was derived by plotting the cumulative distribution of the latency of the SMS messages.
16) Percentage of retransmitted messages – This is the percentage of SMS messages that had to have at least one retransmission sent.

17) Maximum number of retransmissions – For the entire data set, this is maximum number of retransmissions that occurred for a single message.
18) Carrier – The carrier the test utilized for message delivery (for MT Messages) or origination (MO Messages).
19) Date of start of test – The date the first message was sent. The date is in Greenwich Mean Time (GMT.)
20) Hour of start of test – The hour the first message was sent. The time is in GMT.
21) Latitude of first message.
22) Longitude of first message.
23) Average signal strength – This is the average received signal strength Indicator (RF signal strength) as measured by the probe when receiving each SMS message.
24) Mobile or Stationary – This is an indicator as to whether or not the tests were done while the SMS Probe was stationary or in a moving vehicle.

MT SMS Test Results

Scenario	S1	S2	S3	S4
Number of MT SMS Messages Sent	1001	3369	999	1001
Number of Lost MT SMS Messages	0	0	0	0
Number of out of Sequence SMS Msgs.	0	0	0	0
Median of MT SMS Latency	3	3	3	3
Max MT SMS Latency	4	16	16	16
% of messages delivered in 0-4 Sec.	100.00%	99.91%	99.60%	99.60%
% of messages delivered in 5-10 Sec.	0.00%	0.06%	0.30%	0.30%
% of messages delivered in 11-20 Sec.	0.00%	0.03%	0.10%	0.10%
% of messages delivered in 21-60 Sec.	0.00%	0.00%	0.00%	0.00%
% of messages delivered in 61-90 Sec.	0.00%	0.00%	0.00%	0.00%
% of messages delivered in > 91 Sec.	0.00%	0.00%	0.00%	0.00%
Standard Deviation of MT SMS Latency	0.56	0.71	0.66	0.68
67% of messages received within X Sec.	3	3	3	3
90% of messages received within X Sec.	3	4	4	4
99% of messages received within X Sec.	4	4	4	4
% retransmit	0.00%	0.00%	0.00%	0.00%
Max number of retransmissions	0	0	0	0
Carrier	A	A	A	A
Date of start of Test (GMT)	11/5/11	11/5/11	11/6/11	11/7/11
Hour of start of Test (GMT)	0	13	14	3
Latitude of start of test	40.0	40.0	40.0	40.0
Longitude of start of test	-105.3	-105.3	-105.3	-105.3
Average Signal Strength	-80dbm	-80dbm	-82dbm	-82dbm
Mobile or Stationary	S	S	S	S

Figure 5: Mobile Terminated SMS in good RF Coverage Area from Stationary Environment (Note: Figure 5 continued on next two pages.)

Scenario	S7	S9	S11	S12
Number of MT SMS Messages Sent	1300	2002	1001	3002
Number of Lost MT SMS Messages	0	0	0	0
Number of out of Sequence SMS Msgs.	0	0	0	0
Median of MT SMS Latency	3	3	3	2
Max MT SMS Latency	16	28	15	15
% of messages delivered in 0-4 Sec.	99.69%	99.65%	99.80%	99.93%
% of messages delivered in 5-10 Sec.	0.15%	0.20%	0.00%	0.00%
% of messages delivered in 11-20 Sec.	0.15%	0.10%	0.20%	0.07%
% of messages delivered in 21-60 Sec.	0.00%	0.05%	0.00%	0.00%
% of messages delivered in 61-90 Sec.	0.00%	0.00%	0.00%	0.00%
% of messages delivered in > 91 Sec.	0.00%	0.00%	0.00%	0.00%
Standard Deviation of MT SMS Latency	0.73	0.86	0.74	0.66
67% of messages received within X Sec.	3	3	3	3
90% of messages received within X Sec.	3	3	3	3
99% of messages received within X Sec.	4	4	3	3
% retransmit	0.00%	0.00%	0.00%	0.00%
Max number of retransmissions	0	0	0	0
Carrier	A	A	A	A
Date of start of Test (GMT)	10/12/11	11/29/11	12/3/11	12/6/11
Hour of start of Test (GMT)	5	17	23	2
Latitude of start of test	32.7	40.0	37.3	39.7
Longitude of start of test	-117.2	-105.1	-121.9	-105.0
Average Signal Strength	-63dbm	-89dbm	-80dbm	-57dbm
Mobile or Stationary	S	S	S	S

Figure 5 (continued): Mobile Terminated SMS in good RF Coverage Area from Stationary Environment

Scenario	S13	S14	S15
Number of MT SMS Messages Sent	774	1236	4324
Number of Lost MT SMS Messages	0	0	0
Number of out of Sequence SMS Msgs.	0	0	0
Median of MT SMS Latency	2	3	3
Max MT SMS Latency	11	5	40
% of messages delivered in 0-4 Sec.	99.87%	99.84%	99.51%
% of messages delivered in 5-10 Sec.	0.00%	0.16%	0.07%
% of messages delivered in 11-20 Sec.	0.13%	0.00%	0.39%
% of messages delivered in 21-60 Sec.	0.00%	0.00%	0.02%
% of messages delivered in 61-90 Sec.	0.00%	0.00%	0.00%
% of messages delivered in > 91 Sec.	0.00%	0.00%	0.00%
Standard Deviation of MT SMS Latency	0.53	0.43	1.09
67% of messages received within X Sec.	2	3	3
90% of messages received within X Sec.	3	3	3
99% of messages received within X Sec.	3	4	4
% retransmit	0.00%	0.00%	0.02%
Max number of retransmissions	0	0	1
Carrier	B	A	A
Date of start of Test (GMT)	12/7/11	12/8/11	12/8/11
Hour of start of Test (GMT)	16	0	22
Latitude of start of test	40.1	39.7	38.9
Longitude of start of test	-105.1	-104.9	-77.0
Average Signal Strength	-88dbm	-87dbm	-48dbm
Mobile or Stationary	S	S	S

Figure 5 (continued): Mobile Terminated SMS in good RF Coverage Area from Stationary Environment

Scenario	S5	S6	S16	S17
Number of MT SMS Messages Sent	1182	1001	6901	2048
Number of Lost MT SMS Messages	0	0	0	0
Number of out of Sequence SMS Msgs.	0	0	0	0
Median of MT SMS Latency	3	3	3	3
Max MT SMS Latency	32	66	16	18
% of messages delivered in 0-4 Sec.	99.49%	99.50%	99.91%	99.22%
% of messages delivered in 5-10 Sec.	0.08%	0.20%	0.04%	0.24%
% of messages delivered in 11-20 Sec.	0.25%	0.00%	0.03%	0.54%
% of messages delivered in 21-60 Sec.	0.17%	0.10%	0.00%	0.00%
% of messages delivered in 61-90 Sec.	0.00%	0.20%	0.00%	0.00%
% of messages delivered in > 91 Sec.	0.00%	0.00%	0.00%	0.00%
Standard Deviation of MT SMS Latency	1.35	3.12	1040.06	1.05
67% of messages received within X Sec.	3	3	3	3
90% of messages received within X Sec.	3	3	3	3
99% of messages received within X Sec.	4	4	4	4
% retransmit	0.34%	0.20%	0.00%	0.49%
Max number of retransmissions	1	1	0	1
Carrier	A	B	A	B
Date of start of Test (GMT)	11/3/11	10/29/11	12/8/11	12/9/11
Hour of start of Test (GMT)	14	3	16	22
Latitude of start of test	34.0	39.9	39.9	39.9
Longitude of start of test	-81.0	39.9	-105.1	-105.1
Average Signal Strength	-97dbm	-93dbm	-97dbm	-101dbm
Mobile or Stationary	S	S	S	S

Figure 6: Mobile Terminated SMS in Poor RF Coverage Area from Stationary Environment

Scenario	S8	S10
Number of MT SMS Messages Sent	484	243
Number of Lost MT SMS Messages	0	0
Number of out of Sequence SMS Msgs.	0	0
Median of MT SMS Latency	3	3
Max MT SMS Latency	20	17
% of messages delivered in 0-4 Sec.	96.90%	97.53%
% of messages delivered in 5-10 Sec.	2.69%	2.06%
% of messages delivered in 11-20 Sec.	0.41%	0.41%
% of messages delivered in 21-60 Sec.	0.00%	0.00%
% of messages delivered in 61-90 Sec.	0.00%	0.00%
% of messages delivered in > 91 Sec.	0.00%	0.00%
Standard Deviation of MT SMS Latency	1.27	1.19
67% of messages received within X Sec.	4	3
90% of messages received within X Sec.	4	3
99% of messages received within X Sec.	7	8
% retransmit	0.21%	0.00%
Max number of retransmissions	1	0
Carrier	A	A
Date of start of Test (GMT)	11/18/11	11/30/11
Hour of start of Test (GMT)	21	18
Latitude of start of test	39.9	40.1
Longitude of start of test	-105.0	-105.2
Average Signal Strength	NA	NA
Mobile or Stationary	M	M

Figure 7: Mobile Terminated SMS from Mobile Environment

MO SMS Test Results

Scenario	MO1
Number of MO SMS Messages Sent	700
Number of Lost MO SMS Messages	0
Number of out of Sequence MO SMS Messages	0
Median of MO SMS Latency	4
Max MO SMS Latency	7
% of messages delivered in 0-4 Seconds	85.29%
% of messages delivered in 5-10 Seconds	14.71%
% of messages delivered in 11-20 Seconds	0.00%
% of messages delivered in 21-60 Seconds	0.00%
% of messages delivered in 61-90 Seconds	0.00%
% of messages delivered in > 91 Seconds	0.00%
Standard Deviation of SMS Latency	0.57
67% of messages received within X seconds	4
90% of messages received within X seconds	5
99% of messages received within X seconds	5
% retransmit	0.00%
Max number of retransmissions	0
Carrier	A

Figure 10: Mobile Originated SMS Messages

Conclusion:

With 31,868 mobile terminated SMS messages sent (simulating from PSAP to caller), 0 of those messages were lost and 0 of those messages were received out–of-sequence. Of all of those messages, only an extremely small fraction of messages had to be retransmitted. Messages requiring retransmission only had to be retransmitted once. Neither motion nor signal strength had noticeable impact on the latency of the messages. A majority of the messages were delivered within 3-4 seconds.

For the stationary test cases, over 99% of the messages were delivered within 4 seconds. In the mobile test cases, over 99% of the messages were delivered within 8 seconds.

Test results were not noticeably impacted by either times of high traffic, times of low traffic, or by carrier or location.

From the above test results, it is clear that by using techniques such as the 9-1-1 SMSC, SMS can be used to create a very reliable and timely 9-1-1 communication infrastructure.