Design Issues for Wireless 9-1-1 Systems: Wireless 9-1-1 Trunk Sizing Recommendations

By Russ Russell, CM, ENP

Designing a network to handle the wireless 9-1-1 call volume for a public safety answering point (PSAP) is a complex task, particularly since the quantity of trunks selected may be determined by factors other than the wireless 9-1-1 call volume attempts. The typical queuing theory results are affected by several factors including: (1) the merging of wireline 9-1-1 calls into nodes (switches that terminate trunking) common to both wireless and wireline transport, and (2) the fact that PSAPs are not necessarily sized to handle all the offered traffic during busy hours. The purpose of this article is to clarify the issues and provide guidelines and traffic engineering theory to arrive at an optimal solution consistent with the generally recognized P.01 Grade of Service (GOS)[1] requirement. That optimal solution is defined as that network which will provide, within the constraints established by the PSAP authority, the highest GOS, i.e., lowest likelihood that a 9-1-1 call attempted will receive a busy signal.

Wireless 9-1-1 Trunk Sizing

The methodology of wireless 9-1-1 trunk sizing is a significant issue for PSAPs, local exchange carriers (LECs) and wireless carriers. It has implications for customer quality of service and for cost of operations.

Clearly, an insufficient quantity of trunks will result in blocked calls that typically increase the number of call attempts and call failures. If more than one out of 100 call attempts are blocked, then the system performance drops below the standard of P.01 GOS. Thus, when the quality of service deteriorates, the ability of the PSAP to answer 9-1-1 calls declines.

Just as clearly, an excessive quantity of trunks results in undesirable cost of operations for both the wireless carrier and for the PSAP. Additional trunking expense is wasted if trunks sit idle, either because the offered traffic is not sufficient to use them or the receiving node cannot handle the traffic that the trunking offers.

Complications

The lack of specific industry standards for trunk sizing between the wireless carrier's mobile switching center (MSC) and the PSAP's 9-1-1 selective router complicates the issue. This appears to be the case because network engineers who examined 9-1-1 traffic and published their findings have been wireline engineers working on LEC network design. We will start from their recommendations.

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[1] P.01 GOS is a probability statement that no more than one call out of 100 attempts made during the average busy hour will receive a busy signal. P.02 GOS is the probability that two attempts out 100 receive a busy signal.

The generally accepted minimum is two trunks to allow for redundancy, or that quantity which will provide P.01 GOS, whichever is the higher number. The two-trunk minimum exists so that, regardless of the offered traffic, if one trunk fails or is taken out of service the other trunk remains to transport the call. This appears in National Emergency Number Association (NENA) Recommended Technical Standard 03-001, "Network Quality Assurance" (see Table I).

> Table I
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> National Emergency Number Association (NENA) Recommendation: NENA Recommended Technical Standard 03-001 "Network Quality Assurance" provides the following in section 6, "Minimum Trunking Requirements":
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> "In no case is it ever recommended that trunking be designed at less than P.01 grade of service, meaning that no more than one call per hundred be blocked.
>
> "It is also recommended as a general rule the number of central office trunks to the selective router is:
> 1. Up to 10,000 lines = two (2) trunks
> 2. 10,000 lines and up = three (3) or more trunks
>
> "For each additional 10,000 lines an additional trunk should be added."

The second complication with the trunking issue is the question of competent authority. Whose responsibility is it to determine the trunking needs? Who has the expertise to make this judgment? I contend that it is a decision that requires inputs from all involved parties: the PSAPs, LECs and the wireless carrier.

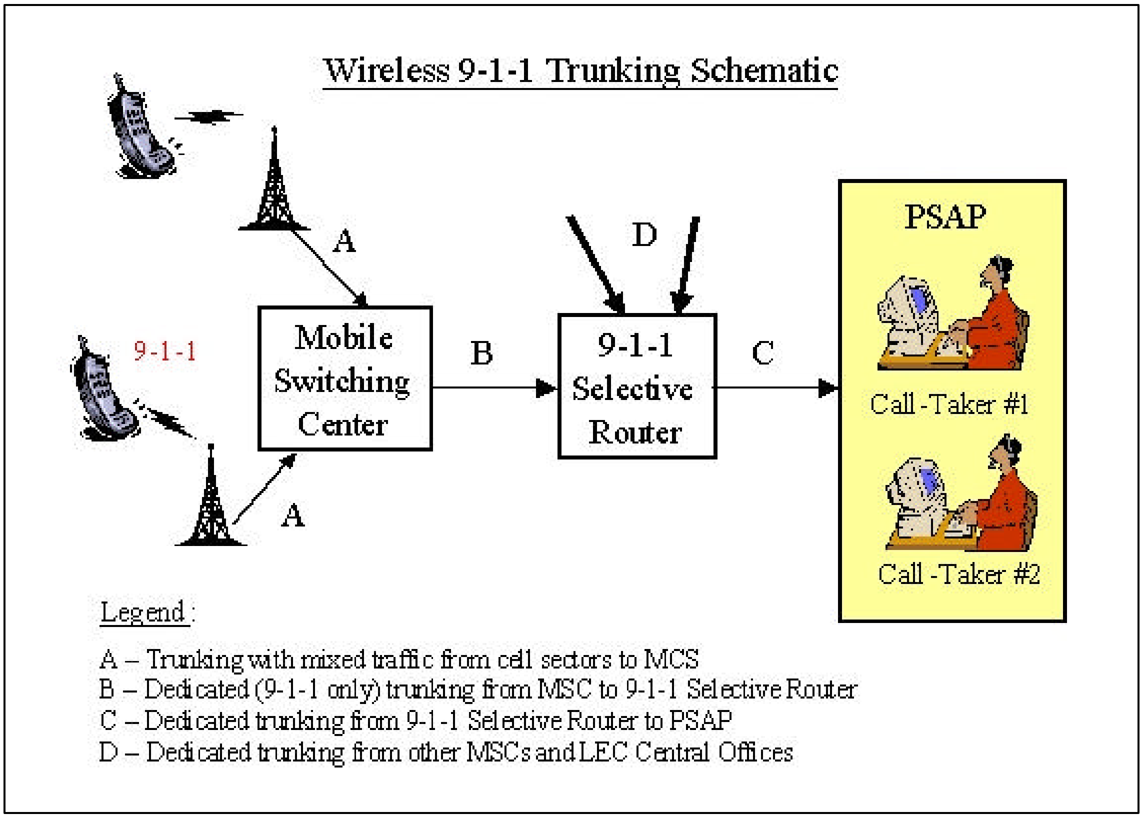
How to Determine Trunk Sizing

There are four key questions related to determining trunk sizing for a wireless 9-1-1 system:

- What critical data are needed to determine trunking requirements?
- What sources can provide that critical data?
- What practices common to PSAP operations should be considered in the process?
- What procedures should be followed to determine the trunking requirements?

Defining the Trunking Needs

There is a need to determine the quantity of trunks that should be established between a wireless carrier's mobile switching center (MSC) and a 9-1-1 selective router (the path labeled "B" in Figure 1 below). As mentioned earlier, the standard methodology uses queuing theory to ensure that the quantity of trunks will carry the expected traffic at a certain standard of blockage, typically P.01 GOS. However, because of other parameters in a 9-1-1 network, this methodology is only the starting point.



For PSAPs *Without* Prior Phase 0 Experience

In wireless 9-1-1, the method with the least service capabilities is called Phase 0. This is when a wireless 9-1-1 call is delivered from an MSC via the public switched telephone network to an administrative phone at the PSAP. Thus, the call comes in without identification of the calling party (i.e., no automatic number information, or ANI) nor automatic location identification (ALI).[2]

If the wireless 9-1-1 Phase I service is being initiated without prior Phase 0 experience, then there is no wireless 9-1-1 call volume statistic. In this case, the quantity of trunks could follow the NENA recommendations in Table I by substituting wireless subscribers for wireline subscribers. Note the inherent problems:

- Roaming mobile users may increase the call volume over what is expected from the number of local wireless subscribers.

[2] However, some MSCs can enable the caller ID feature—a different technology than ANI—that will display the calling number at a caller ID-enabled administrative phone. This is not germane to the trunking issue, but is included here in the interest of being complete in defining Phase 0.

- It is likely that more mobile users will call per incident than landline users. Some PSAP managers claim, "one big traffic accident will generate at least 20 wireless 9-1-1 calls."
- The duration of wireless 9-1-1 calls is typically at least two to three times the duration of the wireline 9-1-1 call because the PSAP call-taker has to verbally gather more information.

To cover these variations, it is recommended that the number of mobile subscribers be reduced from 10,000 per trunk to some lower number, until experience provides more accurate data. This new number of wireless subscribers per trunk will be the traffic engineer's judgment based on the following key parameters:

- <u>Comparison of the number of roamers versus local subscribers</u>. Does the PSAP's jurisdiction include major thoroughfares? How does the population of the jurisdiction differ by day and night, i.e., do office workers come into the area during the day with phones that are roamers?
- <u>Police, medical and fire emergency level of activity in the coverage area</u>. How many wireline 9-1-1 calls do you receive by day, by hour in each day of the week? Are there any major changes in call volume as a result of major events, such as sporting events and festivals?)
- <u>Discussions with PSAP managers on call expectations</u>. Is your PSAP more busy or less busy than others in the area? What is the accident rate on major thoroughfares in your jurisdiction?
- <u>Discussions on 9-1-1 call volume in other areas with Phase I experience</u>. Contact local NENA members to find officials with Phase I experience.

Once these parameters are determined, consider this quantity of trunks to be the number at the end of Step 4 in Table II (see Table II following the article), and continue on with the Table II calculations for the other factors.

For PSAPs *With* Prior Phase 0 Experience

If a PSAP has been receiving wireless 9-1-1 calls via Phase 0, then this experience should provide some data that can be used as a basis for decision. Where there has been Phase 0 experience, the recommended methodology to determine trunk quantities is presented in Table II. It should be noted again that there is no industry standard, but this recommendation is based on telephony standards and common 9-1-1 practices. This recommendation has been developed considering:

- The quantity and duration of the offered (or dialed) wireless 9-1-1 calls per PSAP. (This assumes that the wireless carrier has been able to capture the statistical data on these, but this is not always available.)
- Constraint of trunk quantity currently from the 9-1-1 selective router to the PSAP.
- Willingness of the PSAP manager to install additional trunks if the wireless 9-1-1 traffic load calls for additional capacity.
- Constraint on the quantity of calls that can be handled simultaneously by the PSAP.
- The existence of a call-overflow agreement between the PSAP and another PSAP to handle calls that the responsible PSAP cannot accept.

- The NENA sizing recommendation that 9-1-1 trunking be either two trunks or the quantity that will provide P.01 GOS, whichever is larger.

Industry traffic studies
An industry standard traffic study should be conducted that meets the public safety requirements of the Emergency Communications District or state 9-1-1 authority (whomever has authority over the PSAP) to determine the quantity of trunks required to deliver a minimum of P.01 GOS. Four variable factors to consider in selecting a traffic study methodology are explained as follows.

1. Offered vs. Carried Loads (quantity of calls attempted vs. calls transported)
It is important to distinguish between offered and carried loads on a network. Offered loads include all call attempts made to the network, some of which may not have been carried because of blockage (e.g., not enough circuits routing to the PSAP, not enough answering positions at the PSAP) or failure (e.g., trunk is mechanically broken by backhoe, trunk card fails). When people encounter blockage, they tend to generate additional attempts. When the blockage is removed, the total number of attempts drops because the callers succeed in connecting. Carried loads are those calls attempted and carried through to completion on the network segment(s) being considered.

A key point here is that any current carried load probably does not reflect the reality of wireless 9-1-1 call demand because the carried load is set during peak hours in which bottlenecks can be experienced. For example:

- In Phase 0, there may be a limited quantity of phones at the PSAP that can be accessed simultaneously via the 10-digit emergency number on the PSTN. (The limitation is not likely to be the MSC's quantity of access lines to the PSTN, as they are numerous enough to enable local call completion.)
- In Phase I, there may be a limited number of trunks between the MSC and the selective router, or a limited number of answering positions at the PSAP.

In other words, to say "Our call load cannot be much because we've never received more than two wireless 9-1-1 calls at a time," when there are only two telephone instruments available to take the calls, is meaningless and misleading in beginning wireless 9-1-1 trunk sizing standards. Start with information that reflects reality as much as possible.

Thus, to truly "begin with a blank sheet of paper" in network design you must have as accurate an understanding of the call demand as data permits. That is why the wireless carrier's mobile switching center engineers should provide offered load data, if it is available.

2. Queuing Theory
When a call is blocked, there are three possible responses:[3]

i. *Blocked calls held* (BCH): When users encounter blockage, they immediately redial and reenter the queue. This is the most likely situation for a person dialing

[3] Ibid. Page 818

9-1-1 and should be used unless the 9-1-1 system is set up to place callers in a queue, in which case use BCD (below). This requires the Poisson formula in determining the required quantity of trunks.[4]

ii. *Blocked calls delayed* (BCD): When users encounter blockage, the service mechanism holds them in queue until capacity to serve them is available. This will be rarely used, but is appropriate when the PSAP uses queuing equipment. This requires the Erlang C formula.[5]

iii. *Blocked calls cleared* (BCC): When users encounter blockage, they wait for some time before redialing. This is not likely in the case of 9-1-1 calling, so is not recommended. This requires the Erlang B formula.[6]

(The Poisson, Erlang C and Erlang B formulas are described in The Irwin Handbook of Telecommunications by James Harry Green, IRWIN Professional Publishing, Burr Ridge, IL, 1997.)

3. Traffic Load

This is the product of the number of call attempts and the average holding time of all attempts, expressed in hundreds of call-seconds. For example, if a circuit experienced six 9-1-1 call attempts that averaged 120 seconds (two minutes) each, the group would have carried 720 call-seconds of load (six attempts X 120 seconds per attempt). For engineering purposes, the number of call-seconds is divided by 100 and expressed as "hundreds of call seconds" (CCS). Since there are 3,600 seconds in an hour, a load of 36 CCS represents 100% occupancy of a single circuit for one hour.[7] Traffic loads are also expressed as Erlangs, one of which is equal to 36 CCS. The critical data here are:

- The number of 9-1-1 call attempts
- The average holding time of all call attempts

Traffic load data should be available from the PSAPs. The recommended process requires the call statistics programs to segregate calls coming in from the wireless trunks or that are otherwise identified as wireless (e.g., by the pANI, emergency services routing digits or emergency services routing key). Please note that since this traffic load pertains to the MSC-to-selective router trunks that may serve several PSAPs, information has to be collected from all PSAPs involved.

4. Busy Hour Determination

Since networks must handle peak loads, a designer needs to know the heaviest load periods, which is defined as the busy hour. This is not a single hour but rather a composite network design point, leveled to represent a design peak.[8] There are two primary methods to calculate the busy hour:

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[4] Ibid. Page 821
[5] Ibid. Page 821
[6] Ibid. Page 821
[7] Ibid. Page 818
[8] Ibid. Page 823

- 10-High-Day (10HD): This averages the amount of traffic in the busiest hour of the 10 days during the year when the highest traffic load is carried. It is used for network switching.
- Average Bouncing Busy Hour (ABBH): This is the average of the daily busy hour throughout the course of the study—which may be a different hour on different days, hence the "bouncing" period. The duration of the period is determined by the characteristics of the traffic patterns. Engineers who have done busy hour studies generally consider the ABBH as the preferred method. The cautionary point is that the usual week's duration as the study period may be too short for a PSAP study. The study should include periods that include events that will frequently affect call volume (e.g., when a sports game is being played or as summer or winter tourist season nears its peak).

After the Phase I service has been operational for at least three months, subsequent traffic studies should be conducted to see if the initial determinations are still valid. Changes should be made as deemed appropriate by negotiation between the wireless carrier, the LEC and the PSAP.

A Final Note

Care should be taken to examine the GOS for each element in each path from caller (wireline as well as wireless) to PSAP to ensure there is a balance. Too much capacity in one path will be wasted if the terminating node cannot handle it. Conversely, if a wireless carrier decides to order the minimum two trunks without taking into consideration the wireless 9-1-1 call volume, then that wireless carrier will be putting its customers into a situation where their level of 9-1-1 service is less than that of the customers of other carriers.

Note also the need to plan early to collect the data needed for decision and to communicate freely among the organizations involved.

The P.01 GOS is recommended, as this has been what most 9-1-1 industry professionals believe is the optimal choice (from my personal discussions and review of legislation[9]), although this is ultimately a local decision.

The goal should be to establish a P.01 GOS in each path from caller to call-taker with minimal differences in the GOS of each component, thereby minimizing cost for the overall GOS obtained. This is a mark of a well-engineered 9-1-1 network.

Mr. Russell is a major implementation manager for TSI Telecommunication Service, Inc. and is responsible for working with wireless carriers, public safety answering points and

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[9] Texas Commission on State Emergency Communications Rule 251.10 "Guidelines for Implementing Wireless E9-1-1 Service" b. (7)(A), page 8 or 12, lists NENA 03-002 as an industry standard to be followed. Illinois Title 83, Chapter I, Subchapter f, Part 725, Subpart E, c) "Each trunk group should be sized to deliver calls to the selective routing switch being engineered in such a manner that will meet or exceed P.01 grade or service."

local exchange carriers. TSI offers INPosition℠ Wireless 911 as an open IN-based service bureau solution that meets FCC Phase I requirements with an easy migration path to meeting Phase II requirements. For additional information about TSI, contact Russ Russell at (817) 684-1911, email rrussell@tsiconnections.com, or visit the TSI web site at www.tsiconnections.com/ps_inposition_911.htm. (This information is a brief overview and should be used for informational purposes only. Neither Mr. Russell nor TSI warrant the information and neither shall have any liability whatsoever for damages, loss of anticipated profits or other economic loss in connection with or relating to its information.)

Table II

<u>Trunk Sizing Recommended Methodology for PSAPs with Phase 0 Experience</u>

1. Once it has been determined which cell sectors take calls for the PSAP's jurisdiction, request the "offered 9-1-1 calls" and "carried 9-1-1 calls" statistics from the wireless carrier for these cell sectors.

2. Do a Four High Week, Average Bouncing Busy Hour study of wireless "carried" 9-1-1 calls from the cell sectors to the mobile switching center, or MSC (coming in on the paths labeled "A" in diagram above), that serves a particular PSAP. This determines the traffic load for that PSAP for the "carried" 9-1-1 calls and is considered to be the most applicable call volume (See discussion in Step 3.).

3. If the "offered" 9-1-1 call volume is available, repeat the calculation to determine the traffic load if all calls attempts were accepted. With this information, you have reached the <u>first decision point</u>: Since many emergencies witnessed by people with mobile phones will generate more than one 9-1-1 call, should the following calculations be based on the "offered" 9-1-1 call volume or the "carried" 9-1-1 call volume? It is recommended that both calculations be discussed with the PSAP officials as the additional cost to answer "offered" 9-1-1 calls may not provide a higher degree of public service. This "ceiling" may be hit in two ways: (1) The additional wireless 9-1-1 calls concern the same incident as the first call. (2) If wireless trunking (path "B") is increased to handle the load, that increase may saturate the PSAP's ability to answer calls. This can block calls from other MSCs and landline central offices, preventing persons with different emergencies from reaching the PSAP. The decision on which volume to use should be the PSAP manager's, once the cost ramifications are understood.

4. Taking the call volume results decided above, use Poisson Tables to determine the required quantity of trunks needed to provide P.01 Grade Of Service. If this quantity is two trunks or fewer, then select two trunks as the minimum. If this quantity is three or more, select this higher quantity. This is the initial quantity of trunks required for path "B."

5. Consider the quantity of trunks going from the 9-1-1 selective router to the PSAP (path "C").
   a. If the queuing calculations results in the quantity of "B" trunks exceeding the quantity of "C" trunks, then the wireless carrier negotiates with the PSAP to determine if the PSAP will to install additional trunks (path "C") from the selective router.

   b. The 9-1-1 selective router must also route calls from other MSCs and LEC central offices to the PSAP. This requires an input from the LEC's network planner to estimate the loading and enter it into the calculations. For example, if 300 CCS is offered from the new wireless carrier, 250 CCS is offered from an existing wireless carrier, 600 CCS is offered from LEC CO #1, 800 CCS is offered from LEC CO #2, then the trunk requirement (path "C") would be calculated from the sum of those loadings (1,950 CCS).

   c. The LEC's network planner should also determine if there are constraints to increasing trunking, such as port limitations on the 9-1-1 selective router.

Table II (continued)

6. If the PSAP doesn't want to increase the quantity of trunks from the selective router ("C" path), then the maximum quantity of trunks from the MSC to the selective router should be set at the current quantity of trunks from the selective router to the PSAP, pending step 8 below. In other words, there is no throughput gain if the additional input to the node (i.e., the selective router) cannot get out. Since there will always be at least two trunks from a 9-1-1 selective router to a PSAP, the two-trunk minimum standard will be maintained.

7. If the PSAP is willing expand the quantity of trunks from the selective router (path "C"), then note this new quantity and go to step 8 below.

8. The next capacity constraint is the quantity of calls that the PSAP can handle simultaneously. This does not necessarily equal the quantity of PSAP positions. It will be the quantity of calls that: (1) the PSAP can be answering, plus (2) have on hold and (3) have transferred (if the transfer method ties up an incoming trunk). However, this should be offset (i.e., number increased) by any "call overflow" agreements with other PSAPs. Obtain this information from the PSAP manager.

   a. If the call handling quantity is more than the quantity of trunks determined in step 6 or 7 above, select the step 6 or 7 quantity. It will be only one quantity, because the PSAP will have either decided to stay with the current trunks or will install additional ones.

   b. If the call handling quantity is less than the quantity of trunks determined in step 6 or 7 above, select this PSAP capacity quantity. It is not likely that there will be more trunks than call handling capacity.