Office of the Manager
National Communications System
TECHNICAL NOTES

JANUARY 1999 | *TECHNOLOGY AND STANDARDS DIVISION* | VOLUME 6, NUMBER 1

Channel Reservation vs. PACA Queuing: A Comparison of Priority Call Handling Techniques

by Ray Young

Recently, the Technology and Standards Division of the National Communications System (NCS) completed a study that compares channel reservation and priority access channel allocation (PACA) queuing. The study simulated these priority call handling techniques under stress to observe how the techniques would handle periods of extreme congestion. The results of this study are clear: the PACA queuing technique consistently handles network stress most efficiently, providing the best completion rates to national security/emergency preparedness (NS/EP) callers.

This Technical Note explores how channel reservation and PACA queuing treat priority calls, analyzes the simulation's results and presents implications of this study to NS/EP users.

Channel Reservation

Channel reservation handles priority calls by partitioning the available radio channels so that a certain percentage of the channels are accessible only to a certain subset of cellular callers (i.e., NS/EP).

When a NS/EP call is placed, the call is treated like any other call when radio channels are available. When radio channels are not available, the NS/EP call is allowed to compete for a separate partition of the radio channels, with other NS/EP callers of equal or higher priority. If no radio channel is available, including the reserved channels, the call is dropped and the caller must redial to continue to compete for a radio channel.

Channel reservation has advantages as a priority call handling technique. Cellular handsets/mobile stations (MS) already in use could use this service; no upgrades are required. Mobile Switching Centers (MSC) are already being manufactured that can implement the service.[1] Signaling between the Base Station (BS), the MSC, and the MS may be reduced. If the network is congested, this is an important consideration. On the other hand, for this priority call handling technique to work, there must be a declared emergency situation and the service provider must turn the service on. There is a lag period between when the service is first needed and when the service can be provided.

There are two different methods of channel reservation, static and dynamic.

Static Channel Reservation

Static channel reservation works by dividing the set of radio channels into two groups, normal and priority. The priority group can be subdivided down to the callers' priority levels. NS/EP callers compete for channels with callers at the same or higher priority level. Higher priority NS/EP callers are allowed access to the channels reserved for lower priority NS/EP callers. For example, if two channels were reserved for callers at each priority level (assume there are five priority levels), callers at the lowest priority level (level five) have access to two additional channels. Callers at the next priority level (level four) have access to their two additional channels plus the two channels available to the lower priority level callers (four total channels). The use of static channel reservation for priority call handling is described in telecommunication standard ANSI 664: Cellular Features Description.[2] This method is called static because the specific reserved channels remain constant. Figure 1 illustrates the static channel reservation priority call handling technique.

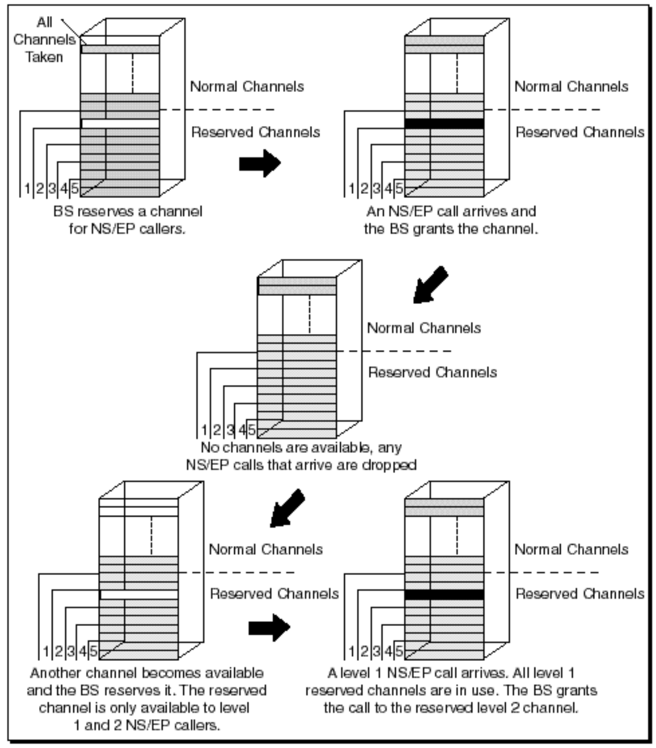

Figure 1. Static Channel Reservation

Static channel reservation has its own shortcomings. This method reduces the potential capacity of radio channels available to non-NS/EP users. Channels could be left sitting available while non-priority callers are blocked from service. Static channel reservation also reduces the potential number of channels accessible to NS/EP callers. If only 10 channels are reserved for priority users, then only 10 NS/EP callers can obtain service when the network is congested.

Dynamic Channel Reservation

Dynamic channel reservation reserves one channel and gives all priority callers the same priority level. When a priority call is made, the reserved channel is assigned. When the next radio channel at the BS is released, it is reserved for the next priority call. If a priority call arrives at the BS before the next channel is reserved, the call attempt is blocked and the caller must try again. This method is called dynamic because the reserved channel varies as radio channels are freed and priority calls arrive. Dynamic channel reservation is not specifically defined within any standard; however, the method is incorporated into many existing MSCs.[1] Figure 2 illustrates the dynamic channel reservation priority call handling technique.

Compared with static channel reservation, dynamic channel reservation uses radio channels more efficiently and can grant NS/EP callers more radio channels. This technique works well when call duration times are short and there is a constant churning of free radio channels.

PACA Queuing

PACA queuing handles priority calls by queuing call attempts when all radio channels are busy. During periods of no radio congestion, priority calls are greated like normal calls. However, when the cellular network becomes congested, priority call attempts are queued. When a radio channel is

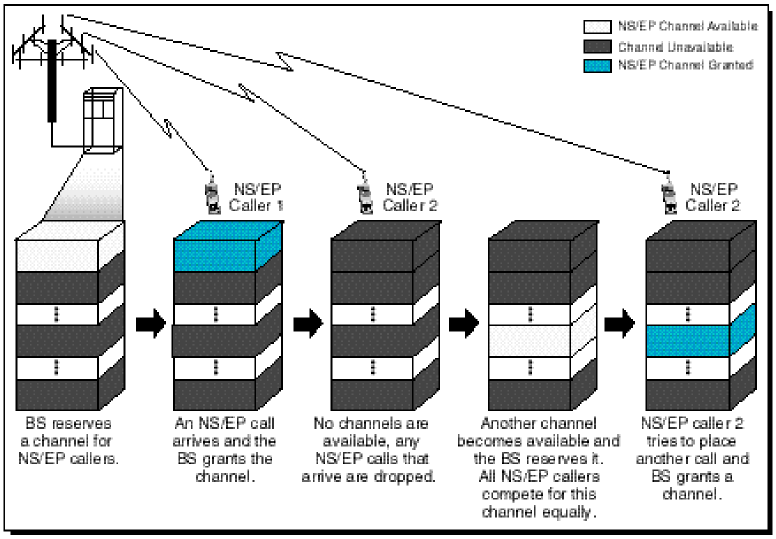

Figure 2. Dynamic Channel Reservation

freed, the calls waiting in the PACA queue are served before incoming call attempts that have not been queued (normal priority-level calls). Priority calls are completed with the highest priority, longest waiting call attempt in the queue completed first. If the queue becomes full and a high priority call attempt arrives, the lowest priority call that has been in the queue the shortest amount of time is removed to make room for the new high priority call attempt. The use of PACA queuing for priority call handling is described in telecommunication standard ANSI 664: Cellular Features Descriptions.[2] Figure 3 illustrates the PACA queuing priority call handling technique.

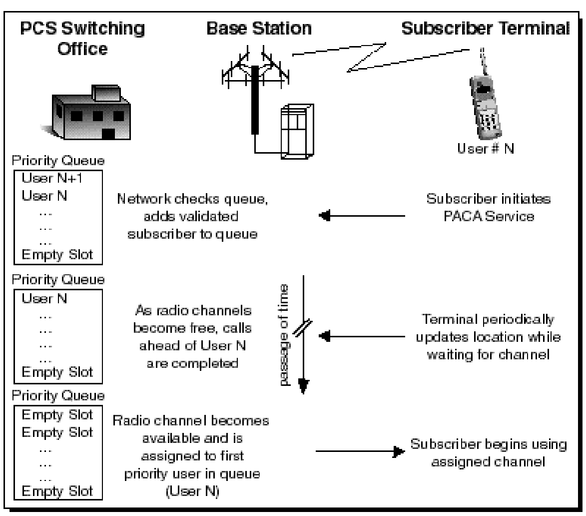

Figure 3. Priority Treatment for NS/EP Telecommunications in a Personal Communications Environment

The PACA queuing priority call handling technique uses the radio resources most efficiently. All channels are available to normal priority calls when network congestion is reduced. PACA is a Supplementary Bearer Service; therefore, the NS/EP caller only needs to enter a feature code to access the service during congestion, unless the subscriber has PACA permanently activated for all call attempts. Either way, no special action from the service provider is required to implement PACA queuing call treatment when the service provider has PACA available within its network.

Messaging Comparison

To understand how channel reservation and PACA queuing differ in treating priority call requests, it is useful to compare how the network entities (MS, BS, and MSC) handle each method. Figure 4 compares these priority call handling techniques. Steps A through D are essentially the same for both methods. At step D, the base station knows that all normal radio channels are unavailable and that the incoming call request is from an NS/EP caller. At step E, the caller is given a reserved radio channel (channel reservation) or is placed in a queue (PACA queuing). If no reserved radio channel is available (channel reservation), the caller must continue to redial to compete for a radio channel. In step F of PACA queuing, the resources connecting the MSC and BS for this call attempt are released; however, resources within the BS or MSC are used to keep track of the PACA queue. Additional signaling is required to notify the caller of the queue status (optional), to send a reorigination request, and to repeat the call origination procedure.

Methodology of Simulation

To compare the priority call handling techniques (PACA queuing, static channel reservation, and dynamic channel reservation), programs were coded to simulate each technique. A large

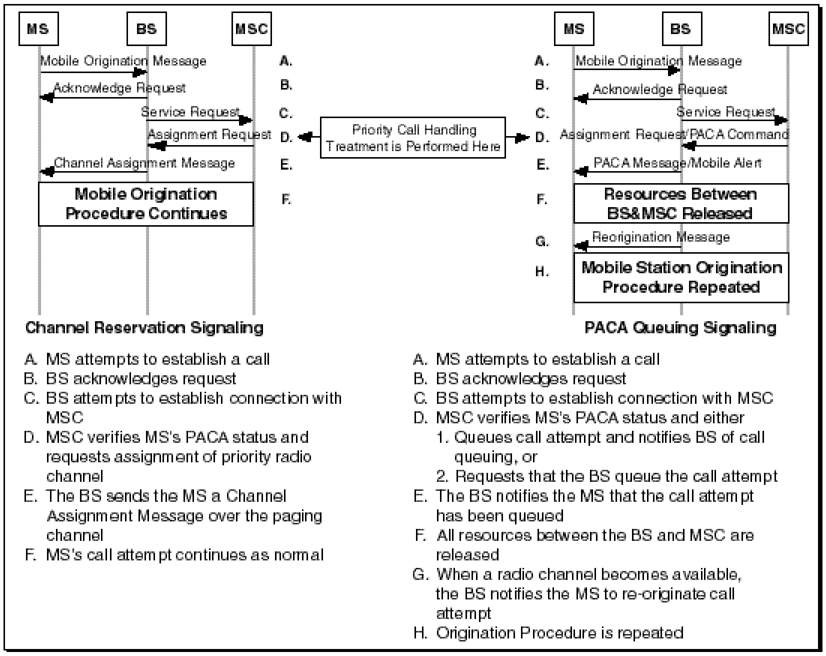

Figure 4. Comparison of Priority Call Handling Techniques–Message Flows

number of call attempts was then sent to each program to see how the methods behaved under stress. Within each program, call attempts arrived sequentially, one call every second. At each iteration, the program checked to see whether any radio channels had become available. The programs randomly assigned call attempts as normal or priority and kept track of the success or failure of each call attempt as it encountered the congested radio channels. When a channel was cleared, a new call was assigned to the channel and given a random call duration length (up to a user-supplied preset maximum length).

Each simulation compiled for 10,000 seconds for each run. After each simulation, data was gathered, including all calls completed, all calls dropped, and NS/EP calls completed or dropped. The programs prompted the user to input values for percentage of NS/EP callers and maximum call length. For all three programs, preset values were selected. During the simulations, maximum call length was held constant while the percentage of NS/EP calls was allowed to increase. On later simulations, the percentage of NS/EP calls was held constant and maximum call length was increased. Simulations were run five times at each value and then an average number was calculated.

Comparison of Simulation Results

At the beginning of the simulations, a set of data was gathered with low concentrations of NS/EP callers (1%) and short average call lengths (150 seconds). At these values, 100% of NS/EP calls were completed when PACA queuing was used, 94% with dynamic channel reservation, and 83% with static channel reservation.

For the first set of simulations, the NS/EP callers were held constant at 1% and the length of the calls was allowed to grow. This simulation represented an NS/EP event like the aftermath of a hurricane, where NS/EP callers are spread out but may need to spend long periods on a cellular phone. Figure 5 shows that for this simulation, even at low maximum call length values, channel reservation provides noticeably lower levels of completions. At 1,500 seconds, PACA queuing is still completing nearly every priority call attempt, while static channel reservation is filling 50% and dynamic channel reservation is filling 70% of incoming priority call attempts.

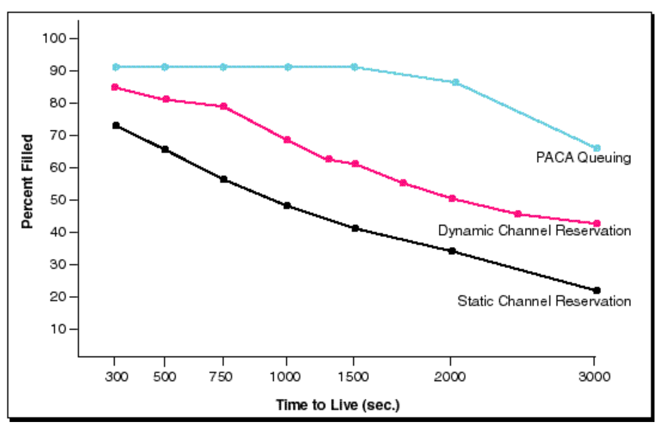

Figure 5. Channel Reservation vs. PACA Queuing: As the Maximum Call Length Grows

Figure 6 graphs the NS/EP calls completed under each method against all calls completed. This graph depicts how close each method comes to seizing all radio channels for NS/EP callers. All three methods perform similarly up to 1,000 seconds maximum call lengths; however, at higher levels of congestion the channel reservation method's completions are bounded, while PACA queuing is able to continue to gain more radio channels.

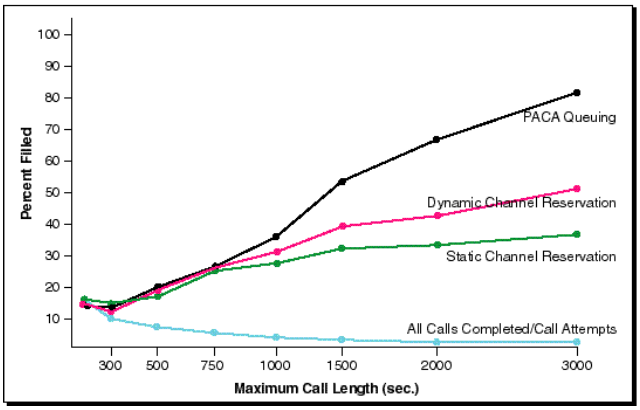

Figure 6. Channel Reservation vs. PACA Queuing: NS/EP Calls Completed/All Calls Completed

For the next simulation, the maximum call length was held constant at 300 seconds, while the percentage of NS/EP callers was increased. Average call length was set at 2-1/2 minutes, based on industry data.[3] By using a 300-second maximum call length and assigning randomly distributed values, the average call is 150 seconds or 2-1/2 minutes. This simulation could be compared to a scenario like a terrorist attack/bombing, where NS/EP callers are concentrated in a small area.

Figure 7 shows the effect of increasing the percentage of NS/EP callers on the network during congestion. This graph demonstrates that even with a low concentration of NS/EP callers, the percentage of completed NS/EP calls drops off sharply with channel reservation. Figure 8 graphs NS/EP calls completed against all calls completed. At low concentrations of NS/EP callers, all three methods provide similar performance. When 25% of the calls were designated as NS/EP calls, 16% of all calls (normal and priority combined) generated were completed. At this percentage, static channel reservation dropped two-thirds of the NS/EP calls, while half of the radio channels were granted to normal priority call attempts. At the same level, PACA queuing completed 75% of the NS/EP calls and used 96% of the available radio channels.

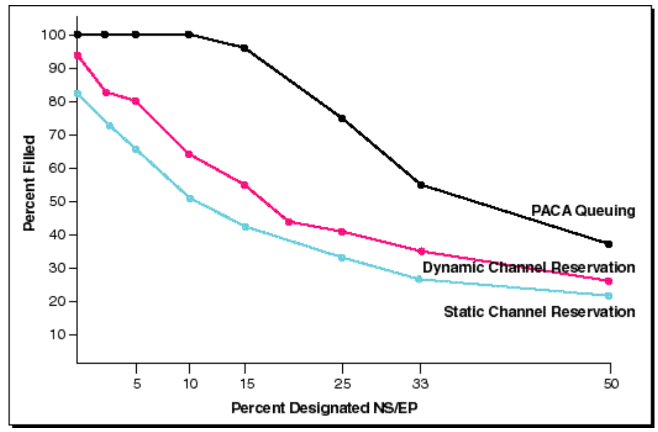

Figure 7. Channel Reservation vs. PACA Queuing: As the Percentage of NS/EP Calls Grows

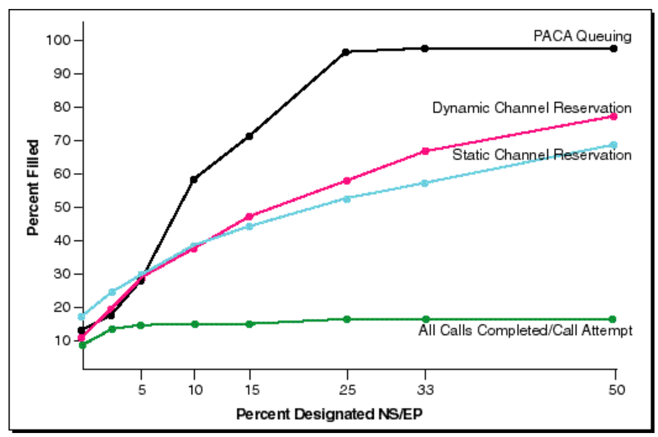

Figure 8. Channel Reservation vs. PACA Queuing: NS/EP Calls Completed/All Calls Completed

One other set of data that was captured concerned how static channel reservation and PACA queuing handled multiple priority level callers. Both programs assigned priority levels with an equal distribution between the levels. In reality, one would expect more callers at levels 4 and 5 than at 1 and 2. The PACA queuing program even allowed lower priority calls to be bumped when the queue was full and a higher-level priority call arrived. Figures 9 and 10 graph the programs' performance handling multiple priority levels. Priority level 5 callers suffer blocked calls in both simulations; however, with static channel reservation, blocking occurs much earlier and at a much greater rate.

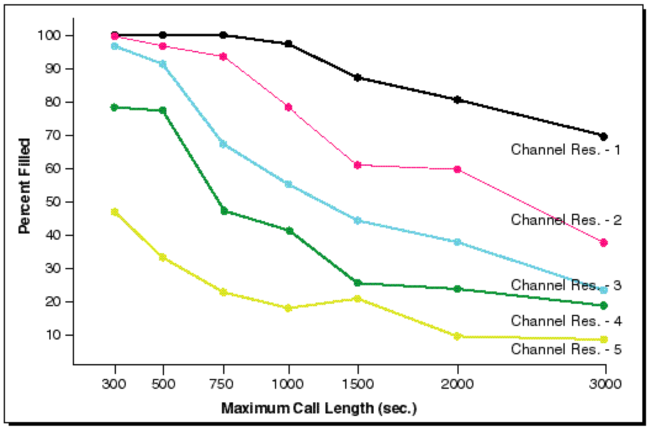

Figure 9. Channel Reservation: Behavior of Each PACA Level as the Maximum Call Length Grows

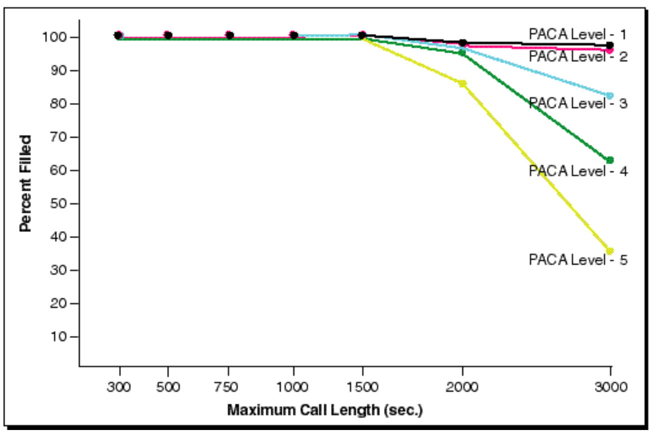

Figure 10. PACA Queuing: As Maximum Call Length Grows

Implications/Conclusion

This study measured the effectiveness of the major priority call handling techniques that provide access to an available radio channel and did not try to account for the other processes needed to complete cellular calls. More call attempts were simulated than one would expect in a real cellular network; however, the data gathered was surprisingly consistent with previous simulations of channel reservation[1] and PACA queuing[3] where more realistic cellular traffic data was used. Therefore, it can be reasonably concluded that gaining access to an available radio channel is the primary key to completing a call during cellular network congestion. To provide the best service to the NS/EP cellular caller, it is vital that the most effective method of providing access to available radio channels be incorporated into the network.

The results of this simulation are clear. As graphed on charts above, the most effective method of serving NS/EP cellular callers during periods of extreme network congestion and call blocking is to implement a PACA queuing solution.

References:

1. National Communications System, "End-to-End Cellular Study and CPS Implementation Strategy," October 5, 1998.
2. TIA/EIA-664, "Cellular Features Description," Telecommunications Industry Association, June 1996.
3. National Communications System, "NCS Cellular Priority Access Implementation Plan," March 31, 1995.

For further information on Channel Reservation vs. PACA Queuing: A Comparison of Priority Call Handling Techniques, contact:

Ray Young
National Communications System
Technology and Standards Division (N6)
701 South Court House Road
Arlington, VA 22204-2198
(703) 607-6200