ALARM NOTIFICATION

Response paging as an alternative to cellular and 802.11 Wi-Fi approaches.

Hospital patient safety demands effective clinical alarm notification. While cellular and Wi-Fi systems can serve this purpose, they lack the necessary performance and reliability to do it safely. Furthermore, notifications from cell phones and tablet computers create distractions and disrupt workflow. A third option, response paging, utilizes dedicated high-power transmitters to deliver alarm notifications quickly and reliably, confirming who receives each message, who reads it, and who will respond.

Document 11-094
Version 1.15

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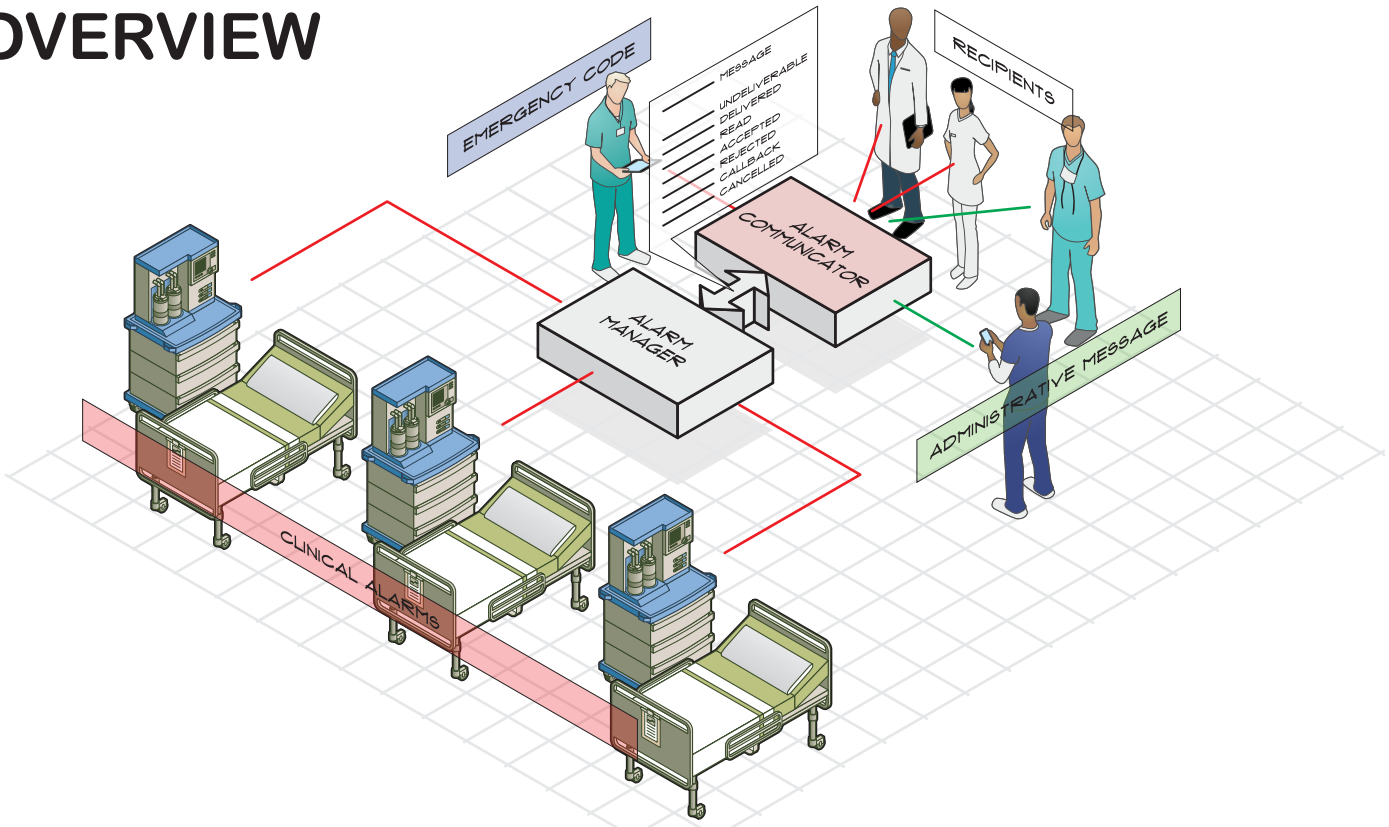


Modern hospitals use wireless technologies to send clinical alarm notifications directly to responding personnel. Such a notification system must also include delivery and read confirmation.

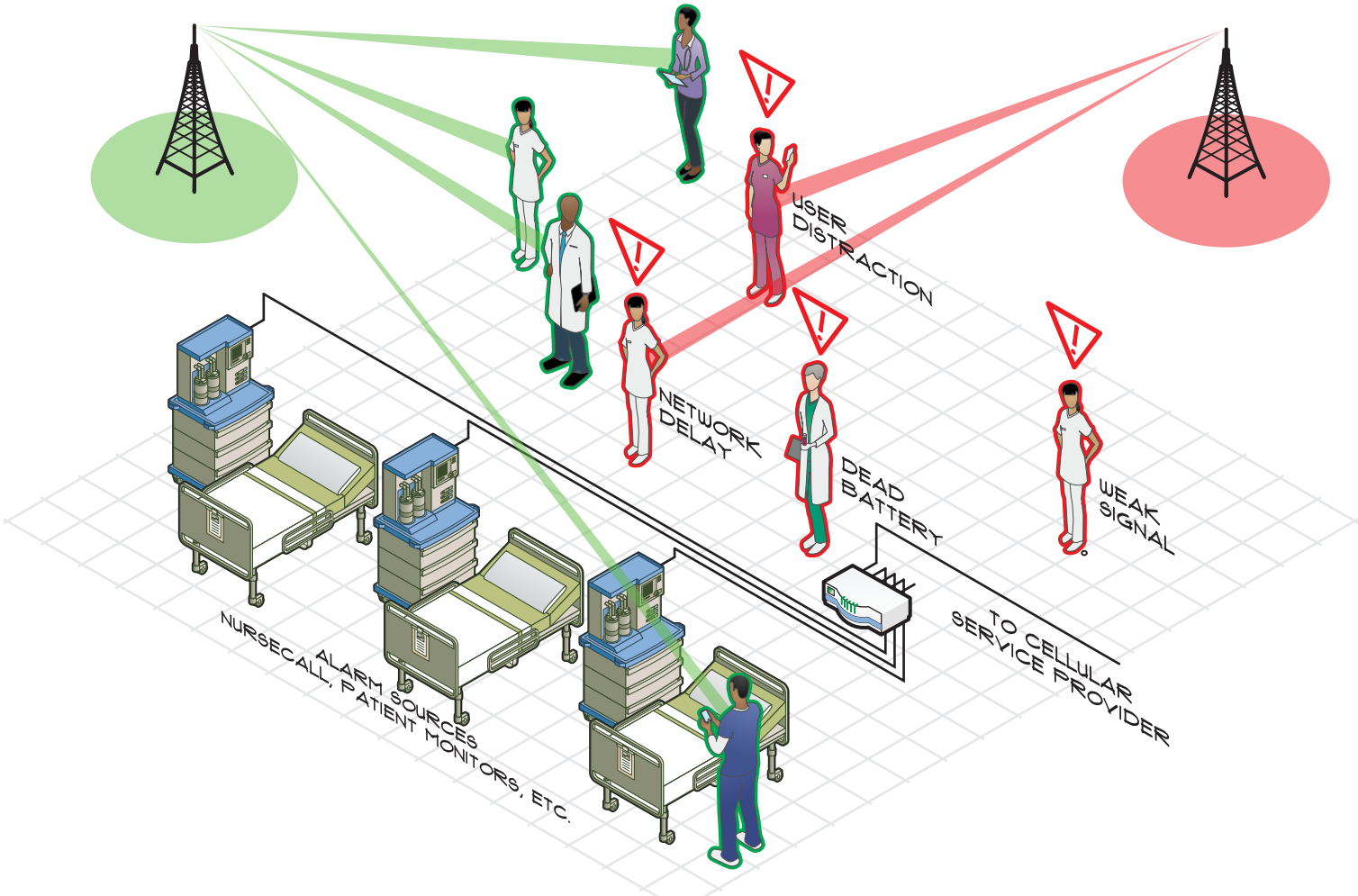
In a hospital, life-critical situations occur hundreds of times every day, detected by bedside monitors, clinical personnel, family members, and patients themselves. These situations result in clinical alarms, which are directed to appropriate personnel, who must take immediate responsive action upon each alarm notification.

Historically, clinical alarm notification has been the purview of dedicated, one-way paging systems. While these systems are simple, fast, and extremely reliable, they cannot confirm message receipt by personnel. This limitation creates an intelligence gap (and associated risk) in patient care, forcing hospitals to consider newer technologies with response capabilities.

In this respect, Cellular and Wi-Fi based approaches are alluring alternatives to dedicated paging systems, as potential "single-device" solutions with rich response capabilities. However, these technologies have serious safety concerns insofar as clinical alarm notification. Wi-Fi systems have endemic problems with areas of poor signal, interference, and node congestion, while cellular systems rely on distant infrastructure which may become unavailable or congested for a variety of reasons. In addition to the problems of availability and performance, Wi-Fi and cellular user equipment creates distractions and disrupts workflow, with occasional deadly effect. In reality, cellular and Wi-Fi approaches can create more patient safety risks than the older paging systems they might replace.

A third option, *response paging*, combines the speed and reliability of traditional paging systems with a state-of-the-art confirmation and reply channel. Response paging delivers the performance, reliability, and simple user experience required for mission-critical applications such as clinical alarm notification, without the compromises seen in cellular, Wi-Fi, and other consumer grade systems.

AVAILABILITY



Cellular-based solutions are susceptible to coverage problems, limited battery life, and distant infrastructure issues, all of which delay critical messages in unpredictable ways.

Mission-critical communication systems are often measured by their *availability*, or the probability that the system will be ready when it is needed. While cellular and Wi-Fi networks have reasonable availability for a commercial product, particularly when measured over long periods of time, they do not have the level of *instantaneous availability* usually associated with mission-critical applications. This creates a significant concern when applied to clinical alarm notification systems.

Cellular System Availability

Cell phones depend on switching centers, base stations, and the public switched telephone network, as well as other local and regional network components. Smart phones have these same dependencies, and also require additional components such as the Apple App Store™, Push Notification Services, the Internet, and e-mail. One server crash can prevent smart phone apps from operating correctly, and natural or man-made disasters can bring down local, regional, or national cell phone services in unpredictable ways, for unpredictable lengths of time. Thus, a cellular-based hospital messaging system is inherently susceptible to local or distant problems well beyond the hospital's ability to control or repair. This is true even if the system uses dedicated hospital base stations because the underlying control systems invariably reside in remote data centers many miles away from the hospital.

The public record contains many examples describing how these dependencies translate into serious real-world problems:

• In 2004 and 2005, several hurricanes and tropical storms caused repeated cell phone outages in Florida, some lasting 3 weeks or more and severely disrupting critical communications for hundreds of police, fire, and EMS services.[1]

• In August 2005, Hurricane Katrina wiped out cell service to every person, hospital, and public safety agency within a several thousand square mile footprint, with outages lasting into the following year.[2]

• In August 2011, Hurricane Irene destroyed 130 cell towers and left another 215 towers without power, leaving 12,000 people and dozens of hospitals without cell phone service for several days in several states.[3]

• In August 2011, a minor earthquake struck Northern Virginia, causing a spike in call volume and social media that disrupted AT&T, T-Mobile, and Verizon Wireless networks in several states for several hours.[4]

• In October 2011, a hardware failure in a RIM server facility disabled the entire Blackberry network in several countries for three days.[5]

• In June 2012, a fast-moving weather storm (derecho) brought down cellular systems in Ohio, Kentucky, Indiana, Pennsylvania, Virginia, and West Virginia, disconnecting 9-1-1 call centers for several days.[6]

• In October 2012, hurricane Sandy flattened cellular networks in several states and disrupted cell phone communications far beyond storm-affected areas for a week or more.[7]

Wi-Fi System Availability

While Wi-Fi systems may not always depend on external elements for proper operation, they nonetheless depend on a myriad of internal components — hundreds to thousands of Access Points (AP's), routers, servers, and applications, plus associated configuration, power sources, and physical wires and cables. Should any one of these pieces become unavailable (e.g., momentarily down for maintenance, down because of hardware problems, etc.), critical messages are not delivered until a technician is able to find, troubleshoot, and resolve the underlying problem.

Additionally, Wi-Fi systems operate using unlicensed, unprotected radio channels, which are susceptible to disruption by smart phones, Bluetooth headsets, microwave ovens, fluorescent bulbs, and even faulty light switches or outlet boxes. For routine use, these problems usually amount to an annoyance. Personnel may occasionally have to reposition their device or step out into the hall to view pharmacy orders or patient history. However, when it comes to alarm notification, these same problems are far more serious. In these cases, responding personnel are disconnected without knowing what is happening, and alarm notifications are missed entirely. This causes unpredictable increases in response delay, compromising

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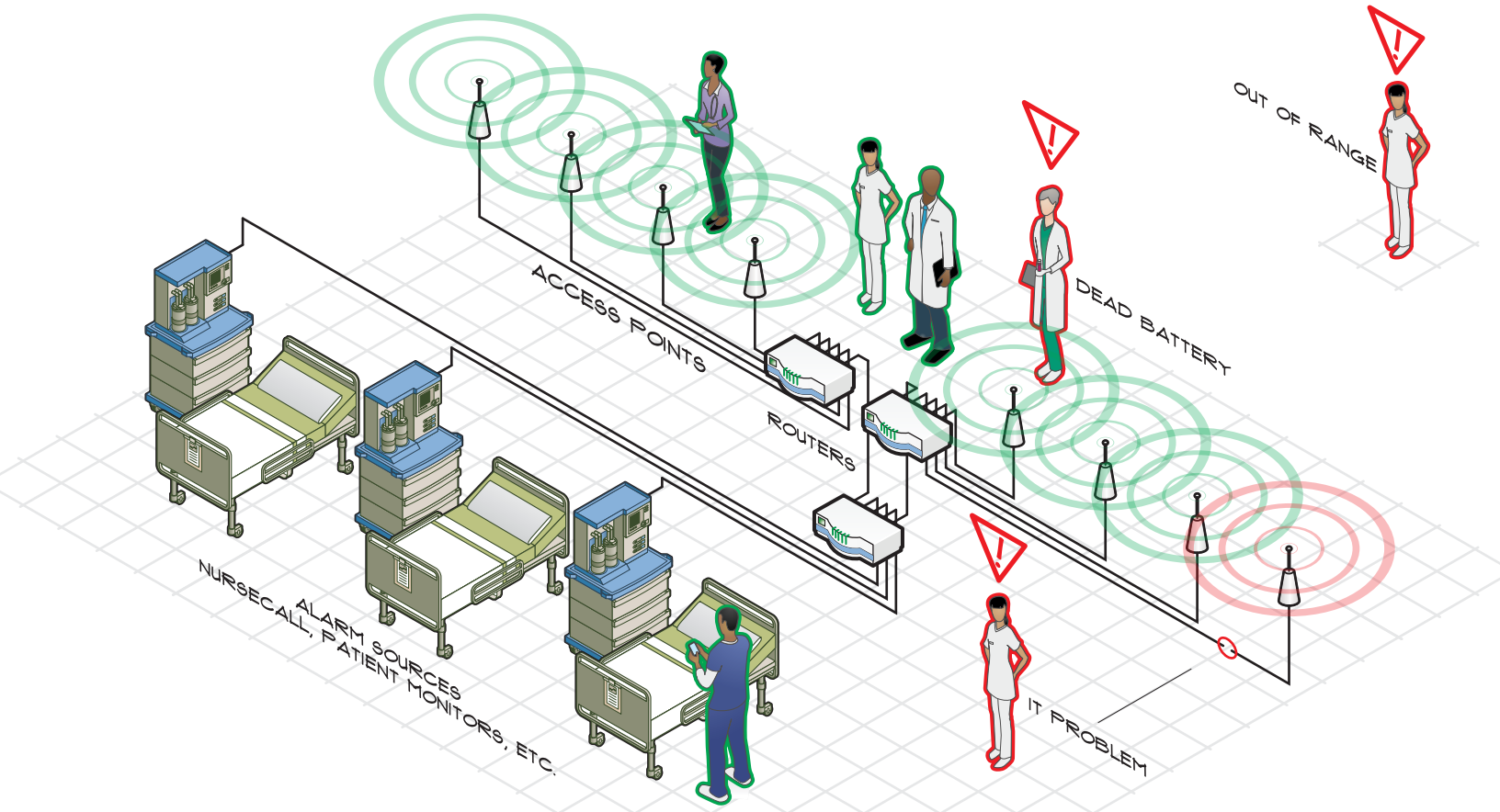


Wi-Fi based solutions are susceptible to coverage problems, IT issues, and limited battery life, all of which delay critical messages in unpredictable ways.

patient safety and increasing risk across the entire hospital.

Cellular/Wi-Fi Handset Availability

A dead battery cannot receive or display alarm notifications, and both cellular and Wi-Fi devices have significant limitations in this respect. While a new battery initially lasts one or two days, clinical alerting ages these batteries quickly with relatively frequent, and deep charge/discharge cycles. After 6 months or so, many batteries will die mid-shift and create significant workflow disruptions.

Furthermore, when personnel fail to notice a dying battery, they once again become disconnected without their knowledge. This results in alarms which are missed entirely, escalations that burden covering personnel, and significant response delays. These problems hurt efficiency and create significant risks for patient safety.

Wi-Fi systems are susceptible to disruption by smart phones, Bluetooth headsets, microwave ovens, fluorescent bulbs, and even faulty light switches or outlet boxes.

PERFORMANCE

The *performance* of an alarm notification system measures the length of time required to deliver a notification message to responding personnel. Although cellular and Wi-Fi systems perform reasonably well in terms of *average performance*, their *instantaneous performance* is unpredictable. These systems may quickly notify personnel of 9 out of 10 clinical alarms, but force the 10th patient to suffer significant delay before help arrives. This unpredictability places patients at risk.

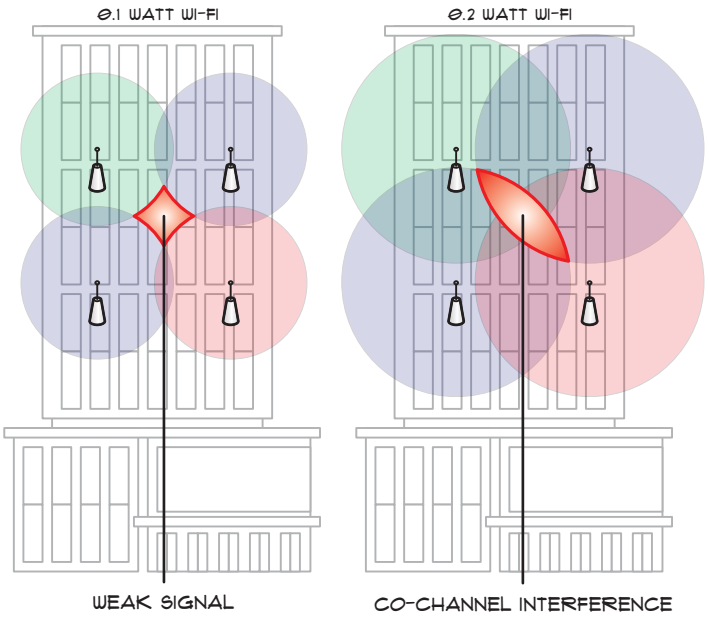
Cellular Performance

All cellular messaging applications rely on the short messaging service (SMS), either to deliver the message directly or to deliver notification that a message is pending. Cellular systems usually deliver SMS messages to a recipient's phone in just a few seconds, or complete a group message in a minute or so. However, cellular companies do not publish SMS performance standards, and these service levels are not predictable. Studies have shown that as many as 9% of SMS messages are delayed more than five minutes, with 5.1% never being delivered at all.[8] Additionally, SMS messages are routed through remote Mobile Switching Centers and SMS Centers, which routinely queue emergency codes behind social media updates and bulk advertising loads. This creates unpredictable delays during periods of distant network congestion.

Wi-Fi Performance

Wi-Fi systems offer more control and dedicated bandwidth to hospitals, but Wi-Fi also involves unpredictable messaging delays for other reasons. For mobile users, AP-to-AP handoff itself represents a service interruption. Under ideal conditions, actual hardware-level handoff is typically very quick, a tenth of a second or less. However end-user applications often suffer 5-10 seconds of total interruption, as noise (SNR) and packet errors begin to increase prior to the handoff event. A message sent to a user moving between areas of a unit can be delayed substantially while waiting for the handoff process to run its course.

Additionally, Wi-Fi systems suffer from an inherent design flaw. As a practical matter, Wi-Fi has only three available RF channels to share among all access points, which is simply not enough for a complex system. Even in a small hospital, the best system design will yield a certain number of inevitable dead spots, caused by low signal levels as well as co-channel interference. These problem areas become more severe as systems get larger, and they cannot be resolved by adding or removing access points. Dead spots cause packet loss and retransmission, which cascades into wildly fluctuating performance for all users sharing the affected access point, even those with good coverage.[9]



Low-power Wi-Fi systems create areas of weak signal, while higher-power Wi-Fi systems create areas of co-channel interference. Both issues delay or interrupt critical messages.

DISTRACTION AND WORKFLOW

An effective notification system must not only alert personnel when necessary, but must accomplish this with minimal distraction and workflow disruption. While smart phones and tablet computers have made healthcare-related data far more available to clinical personnel whenever and wherever they want it, these devices also engage users with a high level of focus and interaction. When used to deliver asynchronous notifications, these devices contribute significantly to user distraction and workflow disruption.

The journal *Risk Management and Healthcare Policy* recently published a risk assessment from several US hospitals, which determined that "*findings from existing work illustrate that smart phones are a significant source of distraction for decision-based activities such as driving, classroom learning, and work-related tasks. Similarly, in health care work settings, these devices pose a great risk.*"[10]

Another study associated each interruption to medical care workflow with a 12.1% increase in procedural failures and a 12.7% increase in clinical errors[13]. Disruptions caused by phone messaging contributed to fatalities documented by researchers.[11]

One such fatality "*involved a resident and intern who discussed the plan of care for a patient while rounding. An attending told the resident to stop warfarin until an echocardiogram of the heart could be taken. While the resident began submitting the orders on her smartphone, she received an SMS text about an upcoming party. The resident chose to respond to the text. The order for the patient was never completed, and the patient continued to receive warfarin for three days.*"[12]

The effects of smart phone distractions go well beyond patient health risks. Studies have shown a general decline in professional relationships due to overuse of text messaging and a decrease in verbal communication. In a study of perfusionists it was "*reported that 55.6% of 439 perfusionists admitted that they used a cellular phone, and 49.2% agreed that they had sent text messages while performing a cardiopulmonary bypass. Some 7.3% of the perfusionists admitted that the cellular phone had a negative impact on their performance. And 33.7% said they had seen another perfusionist distracted by the cellular phone. Of those surveyed, 21% reported having accessed e-mail, 15.1% having used the Internet, and 3.1% having used social networking sites.*"[13]

The very act of receiving a clinical alert on a smart phone or tablet computer is inherently a disruptive event. The user must recognize the alert, distinguish the alerting app from other applications on the device, access the app, and interact with the device to read and respond to the message. The level of distraction is so severe that one study recommends banning smart phones entirely from hospital ICUs and CCUs.[14]

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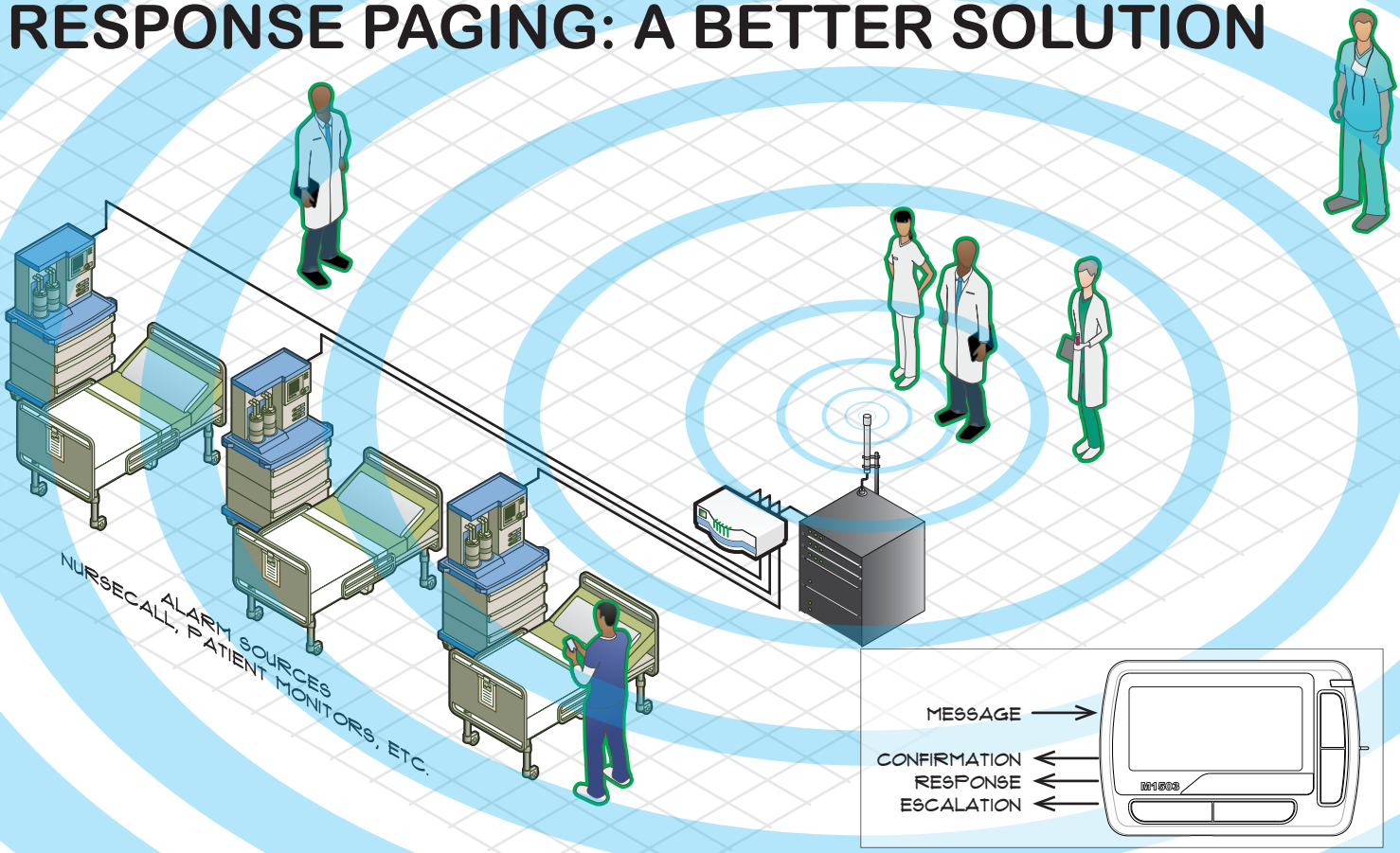
Gill PS, Kamath A, Gill TS. Distraction: an assessment of smartphone usage in health care work settings. Risk Management and Healthcare Policy, August 27, 2012: 111

RESPONSE PAGING: A BETTER SOLUTION



Response paging systems use two synchronized radio channels: a high-power channel to send messages, and a medium-power channel to receive confirmation and responses. One antenna provides reliable coverage to an entire hospital complex.

Response Paging, an evolution of traditional, one-way paging, uses a dedicated, high power transmitter, and adds a second return channel for confirmation and response. Both channels employ digital modulation synchronized together to optimize battery life and performance.

Response pagers include an embedded digital receiver and transmitter, along with a user-friendly interface and a variety of alerting and reply options. When a message arrives, the recipient can read it and reply with a single button press. If already busy with critical care, he or she can escalate the message without removing the pager from the holster or taking time to view it. Pager batteries typically last 2-3 weeks, with periodic recharging by cable or dock.

Compared to other communications systems, response paging offers considerably less bandwidth for data communications; however it also has several important advantages in terms of availability, performance, and user experience.

Response Paging Availability

Like traditional paging, response paging is extremely reliable, with a history of operation even during extraordinary catastrophes. During the 9/11 terrorists attacks, paging systems continued operating properly even after serious infrastructure damage and peak congestion had rendered cellular networks useless.[15] During hurricane Katrina and its aftermath, response paging continued operating properly, despite extensive wind damage, power loss, and flooding that disabled virtually every other communication system and service in the region.[16]

There are several reasons for this. First, unlike cellular and Wi-Fi systems, a response paging system is completely self-contained with minimal

external dependency. An entire hospital system typically fits in a single equipment rack with no external requirement except for power.

Second, response paging systems send messages directly to personnel and receive responses directly from personnel. Instead of multiple access points or base stations, a response paging system typically uses a single antenna to cover an entire hospital complex, plus several miles of surrounding terrain. It operates using dedicated, protected, FCC-licensed channels, and it suffers none of the issues related to AP-to-AP hand-off, weak signal, or co-channel interference. Moreover, the simplicity of this type of system permits affordable redundancy on all levels, providing additional protection against unforeseen circumstances.

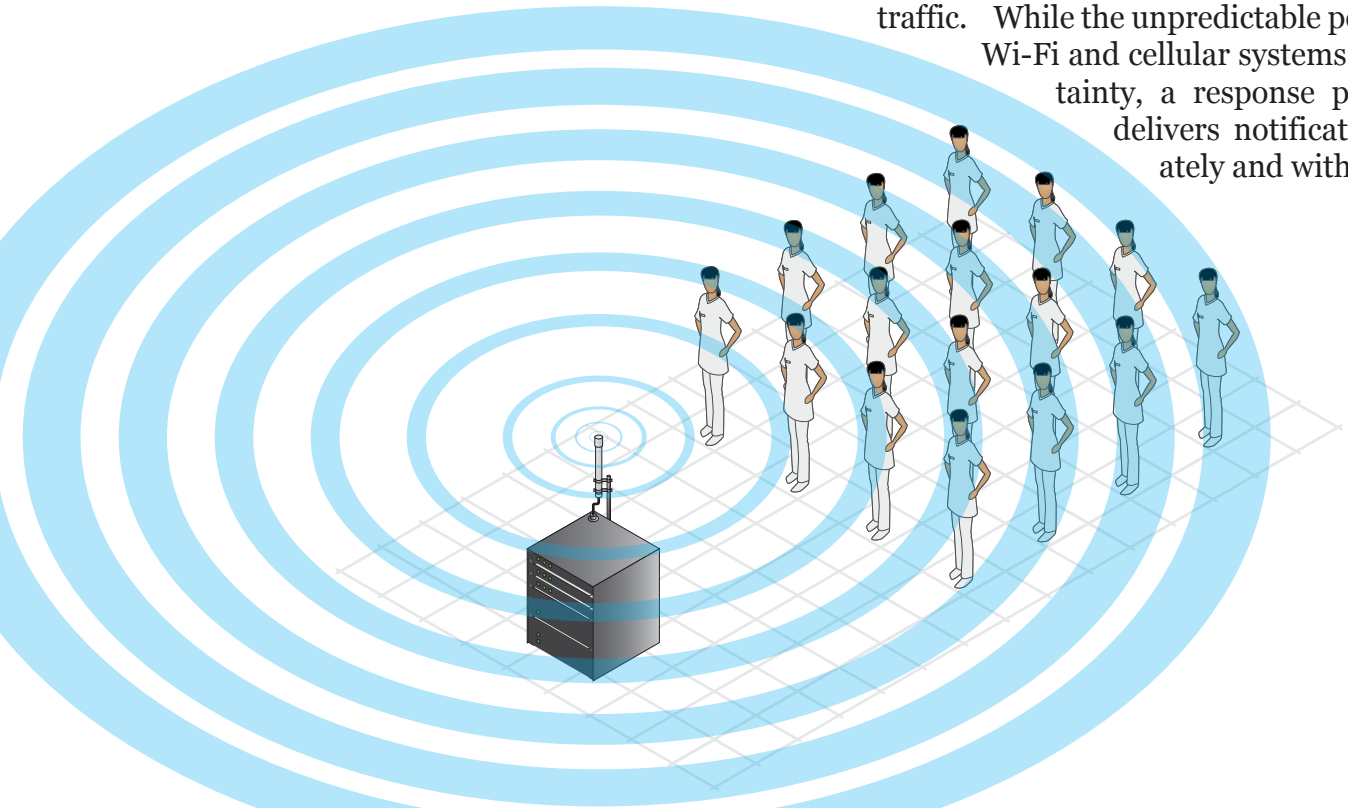
Response paging is designed from the ground up for critical messaging and mobile users. It eliminates the reliability compromises seen with comparable cellular and Wi-Fi approaches, and delivers alarm notifications to responding personnel with certainty.

Response Paging Performance

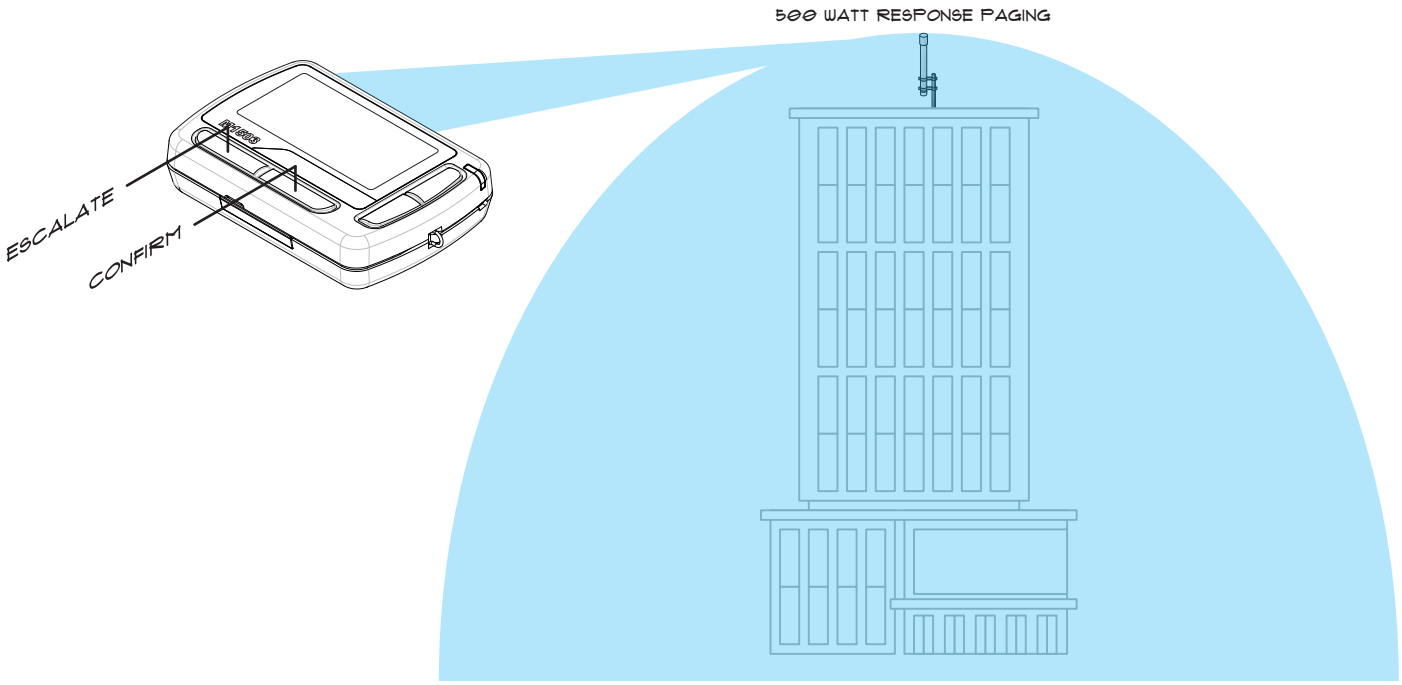
A response paging system avoids the unpredictable performance of cellular and Wi-Fi systems by working in a fundamentally different way. First, it processes group messages natively, notifying one recipient or hundreds of recipients within 5 seconds. This technology, called *confirmed data broadcast*, operates at the hardware level (OSI layer 2), permitting multiple pagers to receive the same RF transmission simultaneously. Other solutions (such as cellular and Wi-Fi) must break group messages into a series of individual messages at the application layer (OSI layer 7), with delivery performance depending on group size.

Secondly, since response paging systems use a single antenna, they do not suffer the RF performance degradation inherent with multiple access points or distributed antenna systems. This simplicity translates into far more successful first delivery attempts, fewer packet retries, and fewer message delivery delays.

Finally, a response paging system uses deterministic, prioritized scheduling to send critical messages immediately regardless of lower priority traffic. While the unpredictable performance of Wi-Fi and cellular systems create uncertainty, a response paging system delivers notifications immediately and without surprises.



With Confirmed Data Broadcast, a response paging system alerts a response group of any size within 5 seconds, then tracks who receives, reads, and replies to the message.



Response paging uses one high power antenna for reliable, uniform coverage. Users receive notifications anywhere within the hospital, and simple user equipment displays messages without disrupting workflow or distracting the recipient.

Distractions and Workflow

In contrast to highly interactive smart phones or Wi-Fi devices, pagers represent an entirely different paradigm: an alerting appliance. They are inconspicuous, attracting no attention during routine workflow. However, when they receive a notification, they alert loudly and display the message prominently along with prompts for clear and simple response action. Personnel who are unable to respond (e.g., already delivering critical care) can escalate a message without even looking at the pager. There are no complex interfaces to distract providers from their tasks at hand, no requirement of interaction, and no reason to even think about the pager unless it is delivering a critical message.

Pagers are fast, reliable, and durable, and they offer by far the simplest possible user experience. Their batteries last for weeks between charges, minimizing any risk of low battery during a shift and greatly simplifying logistical support. They are also small and light enough to clip to a belt or pocket or hang as a pendant. Their simplicity and clarity help reduce the overall burden on clinical staff and the related level of mistakes and risk.

For clinical alarm notification, the advantages of response paging easily outweigh its narrow channel bandwidth. This balance creates a highly reliable and deterministic solution that improves both patient safety and overall workflow efficiency.

During hurricane Katrina and its aftermath, response paging continued operating properly, despite extensive wind damage, power loss, and flooding that disabled virtually every other communication system and service in the region.

Independent Panel Reviewing the Impact of Hurricane Katrina on Communications Networks. Report and Recommendations to the Federal Communications Commission, June 12, 2006

CONCLUSION

Patient safety depends on effective alarm notification. When used for this purpose, cellular and Wi-Fi systems lengthen response times unpredictably, and their complex user experience disrupts workflow as well as the response process itself. In contrast, a response paging system delivers fast and reliable alarm handling with a simple and consistent user experience. This ensures patient safety and reduces risk without compromise.

A response paging system is simple, fast, reliable, and cost-effective. It operates on dedicated, FCC-licensed channels, using high power transmitters, self-reliant control equipment, and simple-to-use pagers. Critical messages are delivered quickly to the correct personnel, who get the message at a glance without disruptive user interaction, spotty coverage, or reliance on external equipment. Messages are confirmed, escalated as necessary, and stored for long-term record keeping.

With unmatched performance and reliability, flawless RF coverage, and a straightforward user experience, response paging is the best overall solution for hospital alarm notification.

With unmatched performance and reliability, flawless RF coverage, and a straightforward user experience, ***response paging*** *is the best solution available for hospital alarm notification.*

ABOUT CRITICAL RESPONSE SYSTEMS, INC.

Critical Response Systems (Norcross, GA) manufactures mission-critical communication systems, including the SPARKGAP response paging system. SPARKGAP delivers the benefits of response paging to hospitals, with additional enhancements to ensure five 9's availability, 5-second message delivery, HIPAA privacy encryption, and customizable dashboard reporting tools to quickly assess hospital alerting behaviors. For more information regarding response paging and hospital alarm notification, please contact:

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