NPSTC Broadband Working Group

Priority and QoS Task Group

Priority and QoS in the Nationwide Public Safety Broadband Network

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Revision History

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Priority and QoS in the Nationwide Public Safety Broadband Network

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1 INTRODUCTION

1.1 ORIGIN

The purpose of this document is to outline public safety priority and quality of service needs and use cases for the 700MHz Public Safety Broadband Network (PSBBN). The document contains herein the requirements for the Nationwide Priority and QoS Framework. It was developed by the Priority and QoS Task Group (PQTG) of the NPSTC Broadband Task Group through collaborative discussion, and represents, except where noted, the broad consensus of the PQTG.

With substantial support from public safety, the Federal Communications Commission (FCC) has identified 3GPP Long-Term Evolution (LTE) as the access network technology for the PSBBN. Although LTE represents a "how", this document assumes LTE as a constraint. As such, references to LTE will be used to enhance clarity of the public safety need description. Where there is broad consensus on an LTE feature that is appropriate to a given need, this paper identifies that feature and suggests an approach that meets the need, however specific implementation details are intentionally omitted.

The Task Group views the PSBBN as a private network, distinct from public (commercial) networks. It is therefore assumed that the PSBBN will not be subject to the same regulatory regimen as public networks. For the purposes of this document, the relevant constraint is the LTE technology.

Public Safety presents a number of unprecedented prioritization challenges for the PSBBN. First, the PSBBN will be simultaneously shared by many different types of agencies (e.g. police, fire, EMS, etc.) and these various agency types have, in many cases, overlapping jurisdictional areas (e.g. state, county, local). Second, all types of applications (e.g. voice, data, video) now share a common packet-based network. Third, public safety operations are dynamic and it is difficult to assign a single priority to a responder that will meet all their operational needs. These challenges necessitate a disciplined and rigorous approach to the definition of a Priority and QoS Framework suitable for nationwide interoperability and Public Safety.

1.2 SCOPE

Items explicitly included in the scope of this document are the priority and quality of service aspects of:

- Nationwide Interoperability
- Nationwide Priority and QoS Framework for the PSBBN
  - "Default" day-to-day prioritization and QoS capabilities
  - "Dynamic" prioritization and QoS capabilities to meet special incident situations, such as a responder emergency
- Needs pertaining to devices (UEs) and infrastructure supporting the PSBBN
- Specific references to LTE technology for enhancing the description of a public safety need
- Specific needs of public safety applications as they interface with the PSBBN
- Usage of pre-emption on the PSBBN, which immediately discontinues certain responder sessions in favor of allowing other sessions to proceed

- Rate Limiting and Bandwidth Management are controls which can manage how much bandwidth a responder can consume at one time

Items explicitly excluded from the scope of this document include:

- Discussions of how to implement or realize stated needs
- Application level prioritization and Quality of Service techniques (i.e. priority and QoS techniques realized "above" LTE by either infrastructure-based or UE-based applications)
- Settings, configuration, or profile descriptions
- Prioritization and Quality of Service of PSBBN UEs as they roam to commercial or other networks

Application level prioritization and QoS pertains to what may be achieved at the application layer above the LTE bearer plane. For example, a push-to-talk hand set application could communicate with a centralized server that multiplexes and forwards the voice communications with various users within the system based on a talk group identifier. In this case, the centralized server could provide varying priorities and QoS based on user profile as identified within the push-to-talk application itself. These prioritization and QoS parameters would be separate from those established at the bearer plane within the LTE network.

Experience shows that the needs of various public safety agencies are unique and can vary over both long and short time horizons (e.g. over months or years at the long end, and over minutes and hours within an incident at the short end). Therefore, flexibility must be built into any plan regarding priority and QoS. Use of the definitions herein must not eliminate a user entity's flexibility to meet their needs, and must allow agencies to adjust their operations and procedures as experience is gained in using the broadband network. More specifically, many of the needs and requirements reflect the nearer term network and UE capabilities, therefore the Priority and QoS requirements will need to be modified as the network and UEs evolve.

1.3 Areas for Further Analysis

This section enumerates topic areas that the task group identified as requiring further analysis outside the scope of the task group's charter.

1. The relationship between an over-arching national authority, in whatever form, and any regional or statewide networks or network operations requires further definition. In particular, analysis regarding requirements driven by the ability of state, regional or local organizations to implement their own LTE cores, is not addressed herein and requires further study.
2. Specific end-user controls (such as, in a mission critical voice system, the ability to control "remote monitor" and similar functions) is not addressed herein. If, as expected, standards organizations begin to develop interoperable application standards, the detailed control needs of each application should be clearly addressed.

1.4 Governance Issues

During the course of the task group's discussion, the following issues related to governance were identified. The consensus of the group was that, while the governance issues were outside of the scope of its work, they should be captured for further study by an appropriate organization.

1. Adding a new responder, application, or agency to the PSBBN – Public Safety has identified the need for the user entity to determine when new assets (i.e. responders, applications, UEs, agencies, etc.) are added/changed/removed from the PSBBN. The majority of User Entities have further identified the need to control dynamic priority for specialized incidents. Many user entities want to directly perform these system changes themselves, while others have indicated a preference for a service model. Concurrent support for both user-controlled and service models needs to be orchestrated within an overall governance framework.

1.5 DEFINITIONS

ARP	Allocation and Retention Priority – The LTE priority that determines if a new responder resources can be acquired (or if an existing resource should be retained). See 3GPP TS 23.401.
BBN	Broadband Network. Defined as a nationally interoperable LTE network operating in 700 MHz Public Safety spectrum and operating according to requirements defined by Public Safety.
BBNO	Broadband Network Operator. This is the entity in control of the ongoing monitoring and daily operations of the monolithic or distributed BB network. The BBNO could be monolithic (such as a proposed federally created non-profit corporation), or distributed (such as a federation of independently operated regional networks). The distinction between monolithic and distributed governance and operation is not germane to priority and QoS, because this document focuses on the needs of public safety for control in the BB environment as a whole. Regardless of the operations model, the BBNO is assumed to have licensing and oversight management responsibilities and a mandate to ensure interoperability between the user entities.
DB	Database
eNB	Evolved Node-B. This is the LTE base station.
GBR	Guaranteed Bit-Rate
ICS	Incident Command System as defined by NIMS
LMR	Land Mobile Radio
MBMS	Multimedia Broadcast Multicast Service
MUST	The word "MUST" (capitalized) is used herein to identify those items that the task group considered critical to the success of the BB Network. In the opinion of the task group, the network is unlikely to fulfill its mission and promise if these factors are not considered.
NIMS	National Incident Management System
Priority	Focuses on the ability for responders to obtain resources from the BB network, including, but not limited to: • the process of determining who or what can access (attach to) the BB Network • the process of determining who or what can initiate traffic on (i.e. be admitted to) the BB Network. • the process of determining how responder traffic is scheduled for delivery over-the-air
PSBBN	Public Safety BBN

QoS	Quality of Service. Focuses on the quality of experience attributes (latency, packet loss, etc.) supplied by the BB Network to an application or UE..
RMS	Records Management System
Session	Coordinated Priority and QoS involving two or more UEs.
SHOULD	The word "SHOULD" (capitalized) is used herein to identify those items that the task group considered important to the success of the BB network. In the opinion of the task group, the network would benefit from including items so indicated.
User Entity(ies)	Agencies and organizations (e.g. Federal, state , local and tribal) authorized to use the PSBBN as end users.
UE	User Equipment (responder device)
USIM	Universal Subscriber Identity Module

2 Public Safety LTE Priority and Quality of Service

Priority, QoS, and Pre-emption are essential attributes of a mission critical system. Responders must have the resources they need to complete their mission. A nationwide framework is necessary which balances the needs of all agencies sharing the PSBBN, yet the framework must not be too rigid so as to ignore the dynamic nature of incidents.

This section captures public safety needs for the National Priority and QoS framework. It should be emphasized that this framework MUST be applied consistently to all PSBBN infrastructure (especially eNBs) operating at the 700MHz PS spectrum. Failure to apply the framework consistently across the nation would reduce interoperability. For example, if one portion of the network were to offer high priority to voice applications and another portion of the network were to offer low priority to voice applications, national interoperability is lessened between the two areas because resources may not be made consistently available to voice applications. This means PSBBN-authorized UEs MUST be able to utilize any eNB site serving PSBB spectrum and receive priority and QoS according to the national framework described herein.

In order to enhance clarity, this document makes references to LTE technology and this chapter in particular is organized according to the different prioritization mechanisms provided by LTE.

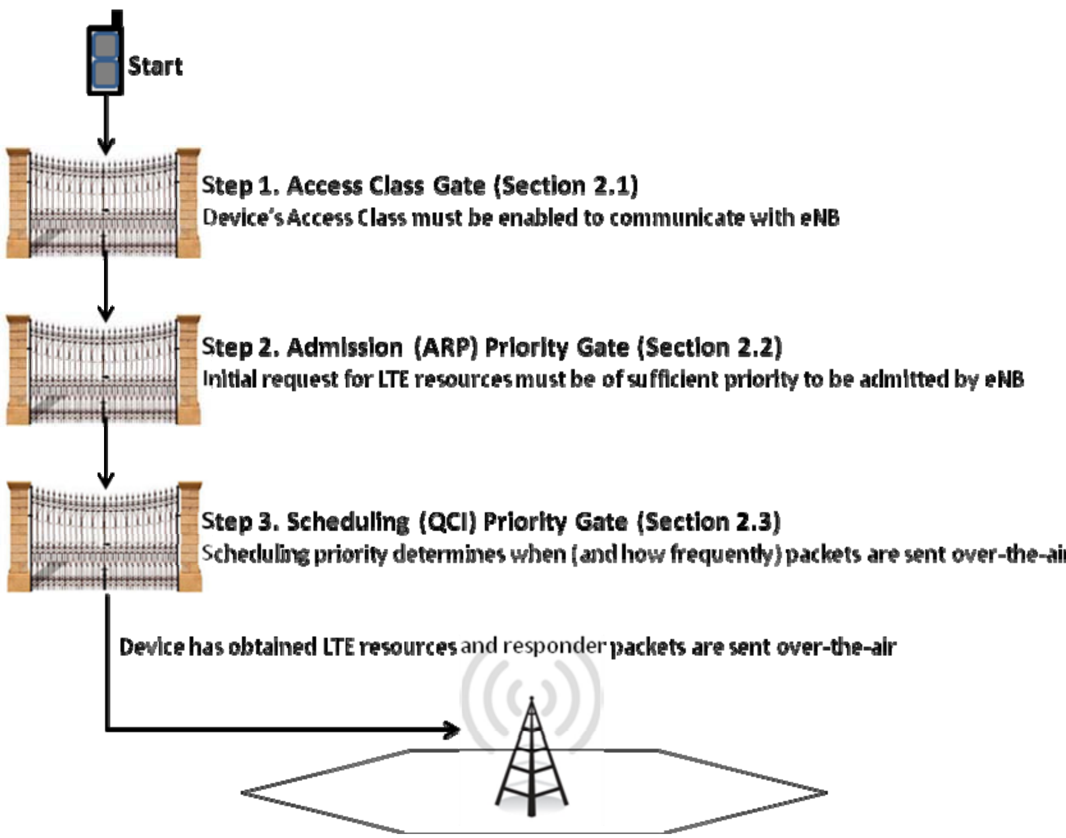


Figure 1: LTE Prioritization "Gates"

In general, an LTE UE (and hence a first responder) must pass the 3 gates shown in Figure 1 before she/he may utilize wireless resources of the PSBBN:

- Access Class Gate – wherein a UE determines that it is allowed to communicate with a particular eNodeB,
- Admission Priority Gate – wherein an eNodeB determines that a UE should be allowed to allocate system resources; and,
- Scheduling Priority Gate – wherein the bandwidth allocated to a particular UE is apportioned and regulated by the system;

The remainder of this chapter will explain public safety needs relative to these gates..

2.1 Accessing the PSBBN Air Interface

Various events such as earthquakes, large-scale medical emergencies, and the like will cause heavy system access. Such events frequently cause a concentration of responders in a given area. This concentration may result in a heavy load at a given cell, and the load may be so severe that a responder's UE is prevented from accessing the PSBBN. While there are substantially fewer users on the PSBBN than a comparative commercial LTE system, care must be taken to prioritize initial system access for the PSBBN user community.

LTE technology provides methods to address this need in the form of Access Class Barring. Details of this capability and public safety recommendations may be found in Appendix A.

Using an administrative terminal, Public Safety MUST be able to assign a UE to one or more prioritized Access Classes, which will determine preferential initial access to the PSBBN. Public Safety MUST further be able to dynamically control which Access Classes are able to utilize the PSBBN in the event of congestion.

2.2 Admission Priority

Admission priority refers to the behavior of the PSBBN as responders attempt to initiate (or receive) service. In light of congestion, this section attempts to define the public safety parameters that are used by the PSBBN in determining whether or not a responder's application should be commenced on the PSBBN.

Admission priority is typically defined by a system administrator or application and is enforced directly by each LTE eNB, independently from other eNBs. Both LTE point-to-point (unicast) and point-to-multipoint (MBMS) resources utilize admission priority.

2.2.1 Default Priority

This section focuses on "default" or "static" prioritization parameters, which would be utilized unless explicitly overridden by dynamic priority (section 2.2.2). Default priority should be thought of as the day-to-day prioritization LTE will automatically provide barring special incidents or needs. Because congestion can occur at any moment, the default priority framework must be carefully designed to accommodate the widest range of responder activites.

Default priority is commensurate with the usual day-to-day functions of a user, as opposed to when that user serves under the ICS structure or other dynamic priority circumstances. When heavy congestion arises, less critical day-to-day communications of emergency response support responders will be subordinated to the typically more urgent traffic of first responders in their area of operation.

Typically, an authorized administrator would configure LTE with default priority rules when the agency is added to the overall nationally-interoperable network. The rules themselves are not usually changed and would remain in effect until special circumstances arise. After initial configuration, the responder would not have to take any action in the field to receive the priority identified in this section.

The network MUST allow for the establishment of differential default priority profiles based on the parameters described in the remainder of this section. The network MUST support combining the given parameters in predictable ways to establish the overall default priority of the responder.

2.2.1.1 Application Type

Traditional LMR systems often maintain a distinction between resources for over-the-air push-to-talk and data services. This provides mission critical PTT services with a pool of guaranteed resources. With LTE, voice and data share a common transport, so this distinction is removed and all applications share the same resources. Bandwidth-intensive video and multimedia services also share these resources. Because voice (PTT and Telephony), data, and video all share a single set of LTE resources, it is important to distinguish the most important applications to help facilitate national interoperability. The PSBBN MUST be capable of distinguishing the type of application a responder is using. As a general strategy, the task group has identified mission critical voice as the highest priority application to use the PSBBN. Every attempt is made to retain mission critical voice even in cases of heavy congestion. The following application prioritization MUST be consistently applied to all PSBBN sites:

1. Mission Critical Voice
2. Data applications (e.g. CAD, DB queries/RMS, location services, dispatch data, responder health/telemetry)
3. Low Priority Voice (e.g. telephony or back-up PTT)
4. Video or Multimedia (e.g. streaming, progressive, etc.)
5. Text messaging, multimedia messaging, file transfers, device management, web browsing

An attempt is made to keep these definitions broad to account for new unforeseen applications. The PSBBN MUST allow for modification of the previous order as the users develop experience with the technology.

2.2.1.2 Responder Function

Many LMR systems today are configured to prioritize classes of responders differently. For example, first responders are generally prioritized higher than second responders or system administrators. In heavy congestion, less-critical groups, such as streets and sanitation may be de-prioritized. For this reason, the PSBBN MUST be capable of distinguishing the responder's overall function when determining the responder's overall default priority.

As of this writing, the final classes of user that are authorized to utilize the PSBBN have not yet been defined.

The task group explored various options to classify Responder Function, however a finalized methodology was not selected.

Option 1 – Classify According to ICS Function

- Users normally chartered with life safety
- Users normally chartered with incident stabilization
- Users normally chartered with preservation of property

Option 2 – Classify According to Responder Type

- First Responders- Those individuals in the early stages of an incident who are responsible for the protection and preservation of life, property, evidence, and the environment, including emergency response providers as defined in Section 2 of the Homeland Security Act of 2002 (6 U.S.C. § 101), as well as emergency management, public health, clinical care, public works, and other skilled support personnel, such as equipment operators, who provide immediate support services during prevention, response, and recovery operations.
- Emergency Response Support - Those individuals who are involved in the critical mission areas surrounding the incident response, such as protecting against the incident, preventing the incident, or recovering from the incident.

2.2.1.3 Home vs. Itinerant Users – Default Priority

By virtue of today's LMR system coverage (e.g. each agency having their own LMR system) or by configuration of an existing LMR system, agencies have a well-defined operating area (e.g. jurisdiction). The definition of an agency's jurisdiction varies with the scope of the agency itself. For example, city, county, and state functions can all overlap.

The PSBBN now combines many agency types onto a single network with a single spectrum allocation. It is desirable to retain the concept of operating area when discussing priority on the PSBBN.

There are many reasons a responder may travel outside her or his home operating area. Some examples include:

- Incident-based Events
    - mutual aid
    - pre-planned events (e.g. sporting events)

- inter-agency service agreement

- Non-incident-based Events
  - training
  - traveling to court
  - on vacation with UE
  - stopping for food
  - vehicular service

Aside from unintentional use of bandwidth outside a responder's home area (i.e. non-incident-based events), there are cases such as mutual aid where it is desirable for a responder to operate with priority outside her/his home area. These are discussed in section 2.2.2.4. Generally, responders can be classified in one of three states:

- Home User (i.e. responder in home area)
- Low Priority Itinerant User (i.e. responder out of home area, not supporting an incident-based event)
- High Priority Itinerant User (i.e. responder out of home area, supporting an incident-based event) – see section 2.2.2.4.

For these reasons, the PSBBN MUST be capable of changing (typically lowering) the priority of Low Priority Itinerant Users. For example, a responder exiting their home jurisdiction to travel to court (who isn't supporting an incident-based event) would automatically (i.e. without human intervention) be de-prioritized in favor of responders home to the area. Implementation MUST allow for cooperating agencies (e.g. mutual aid responders) to not incur degraded communications in fast-breaking incidents that cross operating areas.

2.2.1.4 Controlling Default Priority

The PSBBN is expected to serve many different applications which can be provided locally, regionally, or even nationally. The entity managing each application may or may not be the same. For example, a specialized video application may be deployed by a local User Entity and telephony services may be provided by a national User Entity. Each entity providing applications (local, regional, national) MUST have the ability to establish priority of its applications and responders within bounds established by the national framework on the PSBBN. Following the previous example, the local User Entity would be able to assign default priority values for the specialized video application, whilst the national User Entity would assign default priority values for telephony services, however all assigned priority values would conform to the values outlined in the national framework.

The act of assigning default priority is typically done by an authorized administrator, subject to the terms of governance (see section 1.4), when any of the following are added or removed from the PSBBN:

- responders
- applications
- agencies

As each of these entities is provisioned for use with the system, it is anticipated each would be assigned an appropriate configuration, as described in sections 2.2.1.1-2.2.1.3. For example, a new agency being added to the system would have its home area configured into the PSBBN. The PSBBN will examine these parameters and MUST automatically compute the default admission priority, scheduling priority (e.g. QCI), and bandwidth needs that should be assigned to the combination of responder, application, and agency.

The task group notes that an agreed upon set of administrative procedures SHOULD be established for the purpose of ensuring consistency among jurisdictions controlling default priority.

2.2.2 DYNAMIC PRIORITY

Dynamic priority refers to the ability of an authorized responder or administrator to override the default priority (defined in section 2.1.1) assigned automatically by the PSBBN. Typically, human intervention is required to trigger a dynamic priority change, such as pressing the UE's emergency button or turning on vehicle lights and siren.

In LMR systems, responders effect their priority by changing their operational state (e.g. to a condition). Responders MUST NOT be burdened by the PSBBN with priority control outside of their operational paradigms. The PSBBN MUST support a minimum of four priority-effecting dynamic events:

- Responder Emergency – corresponding to the familiar "emergency" button of LMR systems, and described in more detail in 2.2.2.1,
- ICS Priority – identifying the role of a particular UE in an ICS incident and described in more detail in section 2.2.2.2,
- Immediate Peril – which allows a user to elevate his communications priority when there is an immediate threat to human life (described in more detail in section 2.2.2.3), and
- Itinerant User – which provides dynamic priority to responders operating outside their normal jurisdictional area (described in more detail in section 2.2.2.4).

2.2.2.1 RESPONDER EMERGENCY

Traditionally, the responder can press the emergency button on their LMR device to affect the priority of their push-to-talk application. The emergency button is typically used to indicate a life-threatening condition.

Similarly, the PSBBN MUST support the ability for the end-responder to indicate a life-threatening condition from her/his BB UE and receive emergency prioritization. The entire LTE evolved packet core (EPC) and all PSBBN eNB RAN sites must support the responder emergency function. The enhanced capabilities of the PSBBN can offer more than elevated push-to-talk priority. While it is possible to emulate LMR PTT-based emergency calling, the definition of emergency application(s) should not be as strict on broadband. For example, an agency might choose to use full-duplex telephony with an enabled speakerphone and location services during an emergency. In this context, an emergency application is defined as any application (voice, video, or data) pre-configured by the agency for use when the responder initiates the Responder Emergency function.

When an emergency condition is initiated from the responder's BB UE (e.g. responder presses the emergency button), all emergency application sessions (GBR and non-GBR traffic), as defined by the responder's agency for the UE in the emergency state MUST receive elevated emergency priority from the PSBBN. This MUST take place automatically without an administrator having to manually adjust LTE parameters. If any of the agency-defined emergency applications are already in-use by the responder when the responder initiates the emergency function, the priority of those applications MUST be changed to receive emergency priority. If any of the agency-defined emergency applications are not in use at the responder's UE when the emergency function is initiated by the responder, those agency-defined applications MUST be initiated with emergency priority.

Similarly, the act of clearing the emergency condition MUST return the emergency applications' priority to their normal national framework values. This provides UEs in the emergency state with the greatest possibility for communication even during heavy congestion.

When the responder emergency is activated, it MUST assume top admission priority in the PSBBN. Further, activation of the responder emergency MUST have pre-emptive access to PSBBN resources. In other words, should the PSBBN be congested when a responder activates an emergency, the network MUST discontinue lower priority applications in progress to allow the responder's emergency resource request to be accepted into the BB Network.

Finally, the responder emergency service MUST be available to all responders authorized to use the PSBBN network, however some agencies may not wish to enable the service on all UEs.

2.2.2.2 Dynamic Usage of NIMS ICS

The National Incident Management System (NIMS) includes the Incident Command System (ICS). ICS is a nationwide standard which provides common language, organization, and procedures for addressing any type of incident. ICS is applied on a per-incident basis and may be used by a single agency or multiple agencies performing mutual aid. ICS is especially beneficial in addressing large, complicated incidents.

Once a responder is assigned to an incident and under ICS, she/he is given a role in an incident-specific "organizational chart" with a specific function and well-defined command and control. The responder's ICS role exists for at least a portion of the duration of the given incident. This new role (e.g. dive team specialist) may be different than the day-to-day function of the responder (e.g. firefighter).

The National Priority and QoS Framework MUST accommodate the usage of ICS. The PSBBN MUST prioritize the responder according to the responder's assigned ICS role. This may alter the responder's default priority on the PSBBN.

In an effort to limit technology distractions to dispatchers and command staff, it is desirable that the act of assigning a responder to an ICS role automatically adjust the responder's admission priority on the PSBBN. Similarly, when the ICS incident is completed, the responder is expected to automatically return to her/his day-to-day default priority.

2.2.2.3 Immediate Peril

In cases of heavy congestion at a PSBBN cell, a responder may not be able to initiate (or continue) an application. For example, in-progress video services may be pre-empted. In congestion, the default behavior of this prioritization framework is to favor voice services over video services.

In certain rare circumstances, responders in the field or authorized agency administrators may require the ability to override the default prioritization of the system.

The Immediate Peril function provides the end responder (or authorized agency administrator) with the ability to temporarily override the default prioritization of the system when there is an **immediate threat to any human life** (not just to responders themselves). For example, an EMS operator on-scene may need to use video to consult with doctors regarding a poisoned patient they are serving.

Immediate Peril is a serious end-user control and must be used judiciously. Training and procedures MUST be developed and consistently applied for its use. The following table attempts to distinguish the Responder Emergency and Immediate Peril dynamic priority controls.

Table 2.2.2.3-1 Comparison of Responder Emergency and Immediate Peril

	Responder Emergency	**Immediate Peril**
Triggered/ Cleared By?	1st person (e.g. end responder) 3rd person (e.g. video dispatcher)	1st person (e.g. end responder) 3rd person (e.g. EMS dispatcher)
Why Triggered?	An emergency wherein the responder becomes or is likely to become unable to continue providing their normal function. Responder Emergency should be rarely used.	Used to indicate an immediate threat to human life. This function may also be used, for example, when the destruction of property or other events may imminently endanger human life. Immediate Peril should be rarely used.
How Cleared?	Cleared by entity invoking service	Cleared by entity invoking service or optionally by configurable timeout.
PSBBN's	Offer top PSBBN priority to an	Offer elevated PSBBN priority to

Reaction When Triggered?	agency-defined set of emergency applications. Pre-emption will be used to secure resources for the emergency, if necessary.	some or all applications as chosen by the responder or administrator. Each User Entity MUST be able to configure whether or not Immediate Peril can pre-empt other applications, however Immediate Peril MUST NOT be able to pre-empt Responder Emergency or Mission Critical Voice services.
Example Use Cases	Responder shot, injured, outgunned, trapped in burning building, lost, etc,	Forest fire about to circle campers. Tanker truck about to explode near school, EMT video consultation required with doctor regarding poisoned patient.
How Do You Prevent Abuse?	Alarms to dispatcher/incident command Usage record examination	Alarms to dispatcher/incident command Usage record examination
User Entity Usage	All User Entities have the option to use, but some User Entities choose not to offer the capability (i.e. per-agency configuration)	All User Entities have the option to use, but some User Entities choose not to offer the capability (i.e. per-agency configuration) Additionally, User Entities choosing to enable Immediate Peril MUST be able to configure whether or not the service can pre-empt other services to obtain resources (subject to the previously identified constraints).

It is the intent of the national priority and QoS framework to provide overarching standards and definitions for the use of Responder Emergency and Immediate Peril. These should be routinely enforced regionally or locally, following the provisions for local control in the NPSTC Broadband SoR's governance section. As stated in the introductory text of Section 2 herein, the priority and QoS framework MUST be applied consistently to all PSBBN infrastructure. However, as stated in Section 1.2, experience shows that the needs of agencies are unique, variable, and that flexibility must be built into any plan; local control provisions of the NPSTC Broadband SoR should provide for this flexibility under extraordinary circumstances.

Both the Responder Emergency and Immediate Peril capabilities MUST be able to be used simultaneously by the same responder. Should any applications from the sets identified by Responder Emergency and Immediate Peril be in common, Responder Emergency priority will take precedence.

2.2.2.4 ITINERANT USERS – DYNAMIC PRIORITY

High Priority Itinerant Users are responders operating outside their normal operating area and who are assigned to an incident. This is a common occurrence in cases of mutual aid. For example, a ladder truck assigned for mutual aid may want a video briefing as the fire company drives across other jurisdictions to the incident scene.

The PSBBN MUST allow responder UE(s) to be treated as "High Priority Itinerant Users". This can be accomplished in ways that do not require public safety to manually modify PSBBN parameters. For example, the act of assigning a responder to an incident via the Computer Aided Dispatch terminal or Incident Command System application can automatically designate the responder as incident-assigned.

When a responder is deemed a High Priority Itinerant User, their priority MUST NOT be modified as suggested in section 2.2.1.3. In other words, a responder operating outside her/his normal operating area who is incident-assigned will receive priority as determined by the operating area the user is providing support in. In effect, when a responder is incident-assigned, the priority-lowering processing described by "Low Priority Itinerant Users" is turned off for that responder.

2.2.2.5 CONTROLLING DYNAMIC PRIORITY

Responders and administrators SHOULD not be encumbered with LTE prioritization details and prioritization methods; especially during time-sensitive incidents. The task group envisions dynamic priority changes occurring as part of the responder's (or administrator's) normal activities. For example, rather than an incident commander having to directly program LTE admission priority, it may be adjusted automatically by a dispatch application assigning a responder to an ICS role. Other methods of triggering dynamic priority are envisioned; however these methods are outside the scope of this document. This means responders and administrators MUST have the ability to trigger dynamic priority changes, without being bothered by the exact details of the LTE technology.

Further, the exact dynamic priority values that are used MUST comply with the national framework (i.e. a User Entity cannot choose their own dynamic priority in the system). The criteria used to compute a responder's dynamic priority value are defined in sections 2.2.2.1-2.2.2.2.

The nature of the aforementioned dynamic priority parameters dictates who must be allowed to make dynamic priority changes. For responder emergency, the end responder MUST have the ability to initiate and clear the emergency. For usage of ICS, the authorized administrator, dispatcher, or incident commander are typically the roles that MUST be allowed to trigger dynamic priority.

Generally, the entity requiring dynamic priority is the entity that must be allowed to trigger dynamic priority. This provides for the most prompt and expedient service to public safety. It is not desirable to call a central authority and provide UE identifiers over the phone to adjust priority. This is both error-prone and slow.

The task group notes that an agreed upon set of administrative procedures SHOULD be established for the purpose of ensuring consistency among jurisdictions controlling dynamic priority.

2.3 Scheduling Priority

Once a responder has a resource admitted to the PSBBN (i.e. the prioritization parameters of section 2.1 have been evaluated and the eNB has determined that resources should be granted), scheduling priority determines when traffic should be sent to or received from the mobile UE.

Like admission priority, scheduling priority is typically assigned by an authorized administrator and it is enforced on a per-eNB basis.

Scheduling priority considers the following attributes in both the downlink and uplink directions:

- Packet latency
- Packet loss rate

The 3rd Generation Partnership Project (3GPP) has done considerable research into the scheduling priority needs of applications on LTE. Standardized combinations of the scheduling priority attributes have been defined in TS 23.203 [ref] and are called “QoS Class Identifiers” (QCIs). A QCI is assigned to an LTE resource typically when a new application is added to the system and the QCI is likely not changed thereafter.

After the task group’s review of the standard QCI values (TS 23.203, V8.12.0, Table 6.1.7, inserted below), it has been determined that the standard QCI definitions are suitable and sufficient for public safety applications:

Table 2.3-1 Standardized QCI characteristics

QCI	Resource Type	Priority	Packet Delay Budget (NOTE 1)	Packet Error Loss Rate (NOTE 2)	Example Services
1 (NOTE 3)	GBR	2	100 ms	10^{-2}	Conversational Voice
2 (NOTE 3)		4	150 ms	10^{-3}	Conversational Video (Live Streaming)
3 (NOTE 3)		3	50 ms	10^{-3}	Real Time Gaming
4 (NOTE 3)		5	300 ms	10^{-6}	Non-Conversational Video (Buffered Streaming)
5 (NOTE 3)	Non-GBR	1	100 ms	10^{-6}	IMS Signalling
6 (NOTE 4)		6	300 ms	10^{-6}	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
7 (NOTE 3)		7	100 ms	10^{-3}	Voice, Video (Live Streaming) Interactive Gaming
8 (NOTE 5)		8	300 ms	10^{-6}	Video (Buffered Streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
9 (NOTE 6)		9			

Implementation note – Suggestions have been made to utilize QCI3 for other purposes, such as robotics, however as of this writing standards have not been updated to reflect the public safety need.

By adopting the industry standard QCI definitions, this will enhanced interoperability within the PSBBN and also simplify public safety's ability to roam for added coverage and capacity to non-PSBBN LTE systems.

Should the need arise, LTE does allow custom QCIs to be created.

The BB Network selects the QCI typically based on the type of application being used, and the particular protocol the application is using. The aforementioned 3GPP table recommends an association of application service to QCI.

2.4 Pre-emption and Pre-emtability

Pre-emption refers to the immediate removal of a responder's resources, often without warning to the responder themselves. As of this writing, U.S. public carriers do not generally support pre-emption for UEs roaming onto their system. Pre-emption is also avoided by most LMR system operators today. Instead, talkgroups are prioritized and at worst, responders experience an increased queuing delay during system access.

The environment of the PSBBN is fundamentally different than that of public carriers and existing LMR systems. Unlike LMR, all applications share a single set of PSBBN resources. This means high bandwidth video applications and Mission Critical voice share resources. The Public Safety user community has indicated that, by default, the system MUST prioritize mission critical voice above all other application types (with the exception of responder emergency). During the most congested scenarios, this means mission critical voice will be the last application to be impacted. By default, mission critical voice interoperability MUST be preserved in the presence of congestion in order to retain basic nationwide interoperability.

Public carriers today typically offer a fee-based differentiation of service (e.g. Gold/Silver/Bronze) and this model is typically static (i.e. you are always a Gold user because of what you pay). The PSBBN MUST support situational prioritization (e.g. by incident). This means a given responder's priority may vary based on the severity of the task-at-hand.

Section 2.2 describes a series of static and dynamic parameters that are used by the PSBBN to automatically compute a responder's admission priority (In LTE, this is called Allocation and Retention Priority, ARP, and it contains a number from 1-15; 1=highest priority). This means the parameters in section 2.2 are computationally combined to create a resource's ARP value. The priority number (ARP priority) computed by the PSBBN is also used during the pre-emption process. Should an incoming responder resource request in the presence of congestion have a higher admission priority than an existing resource's retention priority (admission priority is equal to retention priority in LTE) and assuming pre-emption is enabled, the existing resource will be discontinued (pre-empted).

Pre-emption on the PSBBN is required in order to:

- Preserve responder health and the lives of the public
- Insure all responders can interoperate minimally through Mission Critical Voice
- Satisfy the dynamic application needs of the incident (e.g. is video required to save a life?)

For these reasons, the PSBBN MUST support the pre-emption capabilities as outlined in Table 2.4-1.

Key:

POA? – Can the given application pre-empt other applications?

BPOA? – Can the given application be pre-empted by other applications?

Table 2.4-1 PSBBN Pre-emption Needs

Application	Static/ Default Priority		Responder Emergency (5)		Use of ICS (3)		Immediate Peril (5)	
	POA?	BPOA?	POA? (1)	BPOA?	POA?	BPOA?	POA? (2)	BPOA?
Mission Critical Voice (4)	Y	N	Y	N	Y	N	Y	N
Mission Critical Data Applications (CAD, Queries, etc.)	N	Y	Y	N	N	Y	Y	N
Low Priority Voice (telephony, backup PTT)	N	Y	Y	N	N	Y	Y	N
Video or Multimedia	N	Y	Y	N	N	Y	Y	N
File Transfers, Device Management, Discrete Media, Non-Mission Critical Data	N	Y	Y	N	N	Y	Y	N

(1) The exact set of applications used for Responder Emergency is configurable per agency.

(2) The exact set of applications used for Immediate Peril is selected by the responder.

(3) Assumption is that ICS will result in elevated priority, but no change to pre-emption characteristics from Static/Default.

(4) Strategy is to always support MC PTT; even under the most congested situations

(5) Responder Emergency and Immediate Peril will be able to pre-empt all lower-priority applications, but not MC PTT.

By default, only the Mission Critical voice application can pre-empt other applications to obtain resources. When the responder initiates "Responder Emergency", the set of applications chosen by the agency for use during the emergency may pre-empt other applications. ICS is anticipated to offer favored system priority, but not impact pre-emption (compared to default priority). Finally, when the responder uses "Immediate Peril" the set of applications selected by the responder may pre-empt other applications.

As users gain more experience with the system, the priority framework (and pre-emption settings) may need to be adjusted.

2.5 Rate Limiting and Bandwidth Management

Rate limiting and bandwidth management provide public safety with the ability to control the amount of over-the-air resources that are made available to a given responder. Technical details of LTE's standard capabilities may be found in Appendix B.

Under normal circumstances, the amount of bandwidth that is available to a responder can be pre-configured into the PSBBN. When configuring a new UE for use with the PSBBN, the User Entity MUST have the option to limit the maximum bit-rate for general data services (such as using the Internet/Intranet). This will prevent a single responder from dominating non-GBR resources at an eNB. Standards/Profiles MUST be created to consistently apply rate limits per-UE across the entire PSBBN. This allows general data usage (i.e. non-GBR traffic) to be fairly balanced for all PSBBN UEs. In the presence of congestion, the PSBBN must further provide a guaranteed minimum bandwidth for a UE's non-GBR traffic (in order to prevent starvation).

When configuring a new streaming voice or video application for use with the PSBBN, the minimum and maximum bandwidth needs of the application are usually well-known (e.g. codec bandwidth needs). Real-time voice and video applications typically require dedicated PSBBN resources. Therefore, user entities MUST have the ability to configure application minimum and maximum bandwidth needs when commissioning new applications for use on the PSBBN. Because of the high complexity involved, the task group has determined that real-time adjustment of PSBBN bandwidth controls SHOULD be strongly avoided for both UEs and applications. The task group also noted that use cases could not be identified which require this capability.

2.6 Group or Session Priority

Applications such as push-to-talk will utilize group communication. In order to support these groups, LTE technology provides two main types of resources:

- Unicast (uplink and/or downlink resource between an application and exactly one UE)
- MBMS (downlink resource between an application and zero to many UEs)

In LTE, each of these resources may be prioritized independently (i.e. admission priority). This means it is possible to construct a group of two members with 2 unicast resources that are prioritized differently. In itself, this can cause a problem. If one of the responders has a substantially lower (admission) priority in the LTE system, it can reduce the probability the call or session will go through (because, for example, only one of the two responders acquires resources).

The task group did consider these and other use cases. For example, should all group participants be normalized to the same admission priority to increase the probability of the call going through (recalling LMR prioritizes talkgroups today)? After careful evaluation, and the assumption that application priorities exist in contiguous ranges, the task group decided not to recommend any additional requirements for this scenario. The added system complexity to alter participant priority for these scenarios was deemed excessive complexity for minimal gain in functionality.

2.7 BACKHAUL AND IP NETWORK PRIORITY

In order to provide consistent end-to-end treatment of Public Safety traffic, prioritization of PSBBN resources must be provided both over the air as well as within the network infrastructure. Backhaul and IP network priorities MUST be aligned to match the priority of over-the-air resources. The IP transport that is used to carry public safety user traffic between the PSBBN infrastructure elements MUST be configured in a manner consistent with the assigned scheduling priority (section 2.3) of the PSBBN resource. This means a consistent mapping between PSBBN-assigned priority and transport/backhaul priority MUST be devised. Further, this mapping must be consistently applied to the entire PSBBN (all territories). This document does not attempt to require a specific mapping of PSBBN priority to the myriad of backhaul and IP technologies available, however an illustrative example is provided in Appendix C.

Failure to align PSBBN scheduling priority with IP network/backhaul priority will significantly reduce the quality of the end user's experience. For example, voice and video may be choppy (excessive packet loss or delay) or entire sessions may be lost.

2.8 PROVISIONING AND SUBSCRIBER MANAGEMENT

In order to realize the national priority and QoS framework and "gates" described herein, considerable UE provisioning and configuration of the PSBBN is required. It is not desirable to expose detailed PSBBN parameters to authorized administrators. Therefore, when assigning priority to a UE, the network operator MUST have the ability to choose from a list of standardized 'templates'. Templates are intended to simplify the configuration and provisioning process. Each template is further anticipated to include valid values for Access Class, Admission Priority, and Scheduling Priority, which are defined according to the nationwide framework. For example, a "Police – Default Priority" template might include Access Class=14, Admission Role=police, and a list of QCIs available to the UE. Templates may be assigned to individual or groups of UEs as a whole. Both a centralized and remotely accessible (e.g. in-the-field) mechanism MUST be provided for assigning individual or groups of UEs to pre-defined templates. Further, an audit log detailing which authorized administrator made a particular change MUST be provided.

> *Implementation note - Access Class values are normally pre-programmed in the USIM using a random distribution for Access Classes 0-9 and in specific quantities for Access Classes 11-15 by the UICC manufacturer from the factory. Additional Access Class values or changes to existing Access Class values may be modified over the air from a UICC management server. Service subscription settings for QoS which include values like ARP are stored within the network.*

2.9 USAGE RECORDS

The priority and QoS controls defined in this document provide considerable flexibility to both agencies and end-responders. Usage records (sometimes referred to as billing records) help responders and administrators understand how the PSBBN is being utilized.

- The PSBBN MUST provide usage records for individual UEs, for incidents, and for the agency as a whole. This usage information MUST include the level of static or dynamic Quality of Service used for each GBR application. The PSBBN MUST further be able to provide UE usage records for the following priority and QoS services: Responder Emergency
- Immediate Peril
- Usage of the Incident Command System
- Home/Itinerant Status
- Internet Traffic Volume
- Traffic Volume to/from Other Networks

Usage records are further characterized by their timeliness. "Post processed" usage records typically involve a billing system and delivery of the "bill" sometime after usage. "Real time" usage records are usually available to the system administrator to show the near-immediate state of system usage. For the PSBBN, "post processed" usage records MUST be supported and "real-time" usage records SHOULD be supported.

2.10 Inter-System Prioritization

Many use cases exist wherein a responder, using a PSBBN UE, is required to call a commercial device operating on a commercial system and in some cases, the reverse is true as well. Such calls span a public safety system and a non-PS system (such as a commercial carrier). When either the public safety system or the non-PS system is congested, the probability of the call completing is diminished. It is therefore desirable for both calls "out of" and calls "in to" the PSBBN be able to communicate and receive a priority indication to appropriately engage prioritization methods.

As used in this section, a "call" should not be limited to telephony service. A "call", for the purposes of this section, should be considered any media (session-based or otherwise) that must pass between users of the PSBBN and non-PS system.

PS UEs operating on the PSBBN, when attempting to communicate with users operating on other networks, MUST be able to convey end to end priority needs to the interconnected system(s) in order to increase the probability of completing communications during periods of network congestion or impairment. Similarly, when a PSBBN UE receives an incoming call from a non-PS system, it MUST be possible for the originating system to convey end to end priority needs to the PSBBN system in order to increase the probability of completing communications during periods of network congestion or impairment.

3 Priority and QoS Nationwide Survey

In September, 2011 the NPSTC Priority and QoS Task Group created an launched a nationwide web survey attempting to capture the prioritization needs of public safety from a broad perspective. The survey itself was closed on 2/1/2012. This task group wishes to acknowledge the tremendous contributions from Cynthia Wenzel Cole (State of TX) and Jeanne Elder (Highlands Group) to create and manage this survey. The survey was explicitly directed toward technical managers of existing Mission Critical communication systems.

3.1 Respondent Community

In total, there were 174 unique respondents; however some respondents did not answer every survey question.

Table 3.1-1 Priority and QoS Respondent Community

Respondent is part of Radio or System Management team?	Yes: 79.9%	No: 20.1%			
Respondent is an end-user of their current PS Radio System?	Yes: 73.6%	No: 26.4%			
Respondent's Jurisdiction	City: 28.8%	County: 31.8%	State: 30.6%	Federal: 8.8%	Tribal: 0.0%
Respondent's Number of Dispatch Centers	Min: 1	Max: 236	Median: 2	Avg: 11.8	
Respondent's Jurisdictional Size (square miles)	Min: 1	Max: 3,800,000	Median: 900	Avg: 98,681	
Number of Users on Respondent's Network	Min: 1	Max: 100,000	Median: 2,000	Avg: 6,925	

3.2 Survey Responses

Table 3.1-2 provides the Priority and QoS survey results. Each question is traced to requirement sections earlier in this document.

In all but one case, the national survey results directly confirmed the needs captured by this document. Question 16 suggests the prioritization of responders should be altered based on the magnitude (e.g. size) of the incident. After detailed task group discussion, it was determined that usage of the Incident Command System (question 15) encompasses the needs suggested by question 16 and thus "Magnitude of Incident" is not necessary as a prioritization parameter.

Table 3.1-2 Priority and QoS Survey Results

Survey Question	Document Reference	Total Responses					
1. Looking out over the next 10-20 years or so, do you believe Mission Critical Voice (MC Voice) PS LTE Networks will eventually be capable of enabling a Public Safety Agency to replace its narrowband LMR systems and/or radios?	N/A	147	Yes: 49%	No: 31.3%	Unsure: 19.7%		
2. Setting aside whether or not it's technically possible, do you believe broadband MC Voice should evolve such that an agency could use it exclusively and replace its LMR systems and/or radios?	N/A	147	Yes: 34%	No: 17%	Depends on cost: 40.8%	Unsure: 8.2%	
3. (OPTIONAL) If and when PS LTE networks begin using MC Voice, would you choose to deploy it exclusively for your agency and abandon the use of narrowband LMR?	N/A	143	Yes: 15.4%	No: 33.6%	Depends on cost: 36.4%	Unsure: 14.7%	
4a. Think of static priority as the default priority the public safety LTE system automatically gives the responder. This priority is used on a day-to-day basis by LTE in determining whether or not the responder can obtain resources when initiating a new application. Should special incidents arise, static priority may be overridden by dynamic priority parameters (section III), however this question is only focused on the “static” (default) priority. Below are a series of parameters that may be used by LTE to compute the overall static admission priority a responder receives on the system. Identify as many of the parameters as you feel are necessary to derive the responder’s default “static” priority.a. In determining static priority, how important is it to be able to distinguish the type of application used by the responder (e.g. Mission Critical Voice, cellular telephony, data, video)?	2.2.1	134	Critical: 73.1%	Somewhat Important: 17.2%	Occasionally Important: 6%	Not Needed: 2.2%	Don’t Understand: 1.5%
4b. In determining static priority, how important is it to be able to distinguish responders based on their function (e.g. First Responder or other Responders, such as Public Works)?	2.2.1.2	134	Critical: 61.2%	Somewhat Important: 30.6%	Occasionally Important: 6.7%	Not Needed: 0.7%	Don’t Understand: 0.7%
4c. In determining static priority, how important is it to be able to distinguish the responder’s “Present Location” (e.g. in-home jurisdictional	2.2.1.3	134	Critical: 24.6%	Somewhat Important: 40.3%	Occasionally Important:	Not Needed: 7.5%	Don’t Understand:

area or out-of-home jurisdictional area)? In other words, how important is it for the public safety LTE system to be able to prioritize responders operating in their home jurisdictional area differently from responders operating outside their home jurisdictional area. Clarification: This question is not intended to cover the PS LTE to commercial roaming case. The intent of this question is to understand if the system should, for example, lower a responder's priority when they are "passing through" your jurisdiction, but not actively participating in an incident (i.e. they might be on the way to court).	2.2.2.4				26.9%		0.7%
5. What other Prioritization Parameters should be considered? (open ended; see below)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6. Within the Type of Application parameter, please provide a ranking of the application categories below. Keep in mind that if a "High Bandwidth" (BW) service such as video, is prioritized highest, it could potentially prevent access by other applications and users. *** Rank 1-6: 1 = highest, 6 =lowest ***	2.2.1.1	133	MC Voice: Rank=1 Score= 612	PS BB Emergency Rank=2 Score= 577	Data Apps Rank=3 Score= 423	Non-MC Voice Rank=4 Score= 357	Text Msg Rank=5 Score= 337
7. Public Safety requires the ability for an authorized agency-assigned administrator to dynamically control the priority of user traffic on a PS LTE network. Discussion: This question validates the general requirement that the PS LTE Network will need to be capable of accommodating authorized changes in priority initiated from the Network. This functionality is needed to make Dynamic Prioritization possible.	2.2.2	125	Strongly Agree: 64.8%	Somewhat Agree: 27.2%	Somewhat Disagree: 3.2%	Strongly Disagree: 4.8%	Don't Understand: 0%
8. It is important for public safety users to have the capability to initiate an emergency call from their LTE portable or mobile device. Discussion: This question tests the requirement for a basic PS BB Emergency service, which can be consistently deployed across the PS LTE Network.	2.2.2.1	125	Strongly Agree: 86.4%	Somewhat Agree: 11.2%	Somewhat Disagree: 0.8%	Strongly Disagree: 1.6%	Don't Understand: 0%
9. The highest PS LTE Network priority level shall be reserved for use by public safety for emergency communications (e.g. by responders that have activated their "emergency button").	2.2.2.1	92	Strongly Agree: 84.8%	Somewhat Agree: 10.9%	Somewhat Disagree: 1.1%	Strongly Disagree: 3.3%	Don't Understand: 0%
10. All PS BB users, regardless of rank or organization, shall be permitted to initiate an emergency condition from their portable or	2.2.2.1	125	Strongly Agree: 58.4%	Somewhat Agree: 31.2%	Somewhat Disagree: 7.2%	Strongly Disagree: 3.2%	Don't Understand:

mobile device. Discussion: This requirement is in the existing SOR so we are validating the notion that essentially all Public Safety user authorized on the network shall be able to initiate a PS BB Emergency service.							0%
11. The act of a responder initiating an emergency condition shall have the capability to ruthlessly preempt other lower priority traffic on a PS LTE network. In other words, a responder initiating an emergency condition will be able to obtain resources for their emergency call or session even in a congested system.Discussion: Ruthless pre-emption is a network capability which would allow an Emergency service to pre-empt, or knock off lower priority traffic or services during periods of congestion. Due to the obvious potential for disruption, it is assumed that network administrators will be able to configure and control this parameter.	2.4	125	Strongly Agree: 64%	Somewhat Agree: 25.6%	Somewhat Disagree: 7.2%	Strongly Disagree: 2.4%	Don't Understand : 0.8%
12. Homed over Itinerant: Local or regional PS agencies shall have the ability to prioritize their local, Home-based users over other Itinerant/In Transit users who are from outside their Home area but are not assisting local operations. Use Case Reference: This would mean all Agency 1 (1.1.x) units would have priority over Unit 1.2.6 in an Itinerant or In Transit operation.	2.2.1.3 2.2.2.4	125	Strongly Agree: 45.6%	Somewhat Agree: 34.4%	Neutral: 6.4%	Somewhat Disagree: 8%	Strongly Disagree: 4%
13. Response over Itinerant: Local or regional PS agencies shall have the ability to prioritize Response Operations users who are from outside their Home area providing coordinated response assistance over Itinerant/In Transit users. Use Case Reference: This would mean that while in Agency 1's area of control, Agency 2 units 1.2.4 and 1.2.5 in a Response Operation would have a higher priority than unit 1.2.6 in an Itinerant operation.	2.2.1.3 2.2.2.4	125	Strongly Agree: 44%	Somewhat Agree: 38.4%	Neutral: 8.8%	Somewhat Disagree: 6.4%	Strongly Disagree: 1.6%
14. Response over Homed: Local or regional PS agencies shall have the ability to prioritize Response Operations Users over Homed users who are not as critical. Use Case Reference: This would mean Agency 2 units 1.2.4 and 1.2.5 in a Response Operation would have a higher priority than Agency 1 units 1.1.2 and 1.1.3 in a Home	2.2.1.3 2.2.2.4	125	Strongly Agree: 36.8%	Somewhat Agree: 43.2%	Neutral: 10.4%	Somewhat Disagree: 6.4%	Strongly Disagree: 3.2%

Operation.							
15. The default priority assigned to a responder may be altered if that responder becomes associated with a specific role (e.g. Incident Commander), as defined in the NIMS Incident Command System (ICS).	2.2.2.2	125	Strongly Agree: 64.8%	Somewhat Agree: 26.4%	Neutral: 7.2%	Somewhat Disagree: 0.8%	Strongly Disagree: 0.8%
16. The default priority assigned to a responder may be altered for that responder based, if the magnitude of the incident changes.	N/A	125	Strongly Agree: 56%	Somewhat Agree: 36%	Neutral: 6.4%	Somewhat Disagree: 0.8%	Strongly Disagree: 0.8%

Question 5 asked for additional prioritization parameters not explicitly listed in the survey. After review, the suggested prioritization parameters were determined to be accommodated by the framework described in this document.

A. APPENDIX A: ACCESS CLASS BARRING DETAILS

In the event of congestion at a site, LTE technology provides a suite of standard capabilities, called "Access Class Barring" (ACB) features (3GPP TS 22.011), to either block or slow down UEs from accessing the system (i.e. even before Admission Priority, section 2.2, is utilized). When originally developed in 3GPP standards, the capability was intended to allow the network operator to prevent overload of the access channel under critical conditions and to allow a small number of users (e.g. public safety, public utilities, etc.) to receive preferential access to a public commercial LTE system in the event of congestion. It is anticipated ACB to be utilized on the PSBBN according to the following assignments. It should be emphasized that these guidelines MUST be applied consistently across the nationally interoperable PSBBN in order to promote a consistent responder experience.

- Access Classes 0-9: When enabled, the UE waits a random amount of time (with a configurable upper limit) before communicating with the LTE system. Per LTE standard, all PSBBN UEs will be randomly assigned to one Access Class value in the range 0-9 in the UE's UICC.
- Access Class 10: Reserved for 911 emergency access to the system. As of this writing, the exact classification of users authorized to use the PSBBN is unknown. Because of this, it is unclear if 911 service and Access Class 10 will be used on the PSBBN.
- Special Access Classes: In addition to being assigned to an Access Class in the 0-9 range, PSBBN UEs may optionally be assigned to one or more Access Classes in the range 11-15. Responders utilizing the PSBBN are recommended to be assigned to an Access Class from the 12-14 range. For classes 11-15, the class is either barred or not barred from the system (i.e. there is no random back-off).
    - Access Class 11 (BBNO-defined): Should access be granted to these UEs? (yes/no). It is anticipated the BBNO will assign this class, and it is not recommended for responders utilizing the PSBBN.
    - Access Class 12 (TBD): Should access be granted to these UEs? (yes/no). Recommended for use by non-critical users of the PSBBN.
    - Access Class 13 (TBD): Should access be granted to these UEs? (yes/no). Recommended for use by non-critical users of the PSBBN.
    - Access Class 14 (TBD): Should access be granted to these UEs? (yes/no). Recommended for use by police, fire, EMS, and other critical users of the PSBBN.
    - Access Class 15 (BBNO Staff): Should access be granted to these UEs? (yes/no). Recommended for use by operators and administrators of the PSBBN itself.

A given UE may be assigned to more than one Access Class. If any of the UE's Access Classes indicate that the UE may use the LTE system, then the UE may proceed with communication to the LTE system.

Generally, the PSBBN may be configured to utilize ACB, however Public Safety has indicated that whenever possible ACB SHOULD be avoided (i.e. all PSBBN users SHOULD, by default, be able to access the PSBBN). ACB is not utilized in normal day-to-day operation (i.e. responders are not typically barred from the PSBBN). ACB is reserved for special situations with a large number of responders at a given location or incident scene. By allowing Public Safety LTE UEs to access the PSBBN, "more informed" prioritization techniques (such as Admission Priority, section 2.1) may be utilized.

ACB is most useful when distinction can be drawn between the users of the network. For example, if only police, fire, and EMS were authorized to use the PSBBN, the feature would have little value because all responders would be assigned Access Class 14. Therefore, as the final rules for usage of the PSBBN are determined, it is recommended the criticality of the user group be assessed and the user group be assigned an Access Class Value in the range 12-14 (in addition to the required 0-9 class). If a user group is determined to be of low priority on the PSBBN, it is possible for that group to only have an Access Class in the range 0-9 (and not be assigned a value in the range 12-14).

It should be emphasized that once a UE has been admitted to the PSBBN and the UE remains active (LTE connected) on the system, a change in the responder's Access Class will not discontinue (pre-empt) the UE's service. However, should the UE become idle the UE will be required to once again pass the Access Class criteria.

The Access Class values (0-15) are stored in the UE's USIM. Because of this, the UE's assigned Access Class(es) are the same numerical value(s) on both the PSBBN and when roaming to commercial LTE spectrum. Most 'average' commercial users utilizing the commercial LTE system will be assigned Access Classes 0-9. For this reason, only having an Access Class between 0-9 SHOULD be avoided by critical public safety UEs.

When the UE does attempt to access the system, the "establishmentCause" (ref 3GPP TS 36.331) indicates to the LTE eNB, the reason for the connection request. Usage of this parameter on the PSBBN should be studied (considering also the behavior of the parameter as the UE roams to commercial spectrum).

B. Appendix B: Rate Limiting and Bandwidth Management Details

Rate limiting and bandwidth management enables the authorized agency administrator to control the utilization of PSBBN over the air bandwidth resources. There are a number of standard LTE features that can be used to control the amount of bandwidth utilized by PSBBN UEs.

Rate limiting is implemented using controls for non-GBR bearers. For example, the amount of bandwidth a responder utilizes while accessing the Internet can be limited. These controls consist of setting an aggregate maximum bit rate (AMBR) for a UE related to a specific LTE Access Point (APN). For LTE networks, this parameter is the Access Point Name Aggregate Maximum Bit Rate (APN-AMBR). This rate limiting control enforces a maximum aggregate bitrate across all of the UE bearers for one APN (i.e. all non-GBR bandwidth used for a particular IP network). Once the APN-AMBR value exceeded, data will no longer be transported by the PSBBN until the data rate falls under the APN-AMBR value. Another rate limiting control for non-GBR bearers is the per UE aggregate maximum bit rate (UE-AMBR). This rate liming control is enforced across all non-GBR LTE bearers that are associated with a UE, independent of the bearer's termination point (APN). The LTE network will allow rates up to the value of the UE-AMBR for a UE, and once above this value, data rates will be throttled. Once the UE's aggregate bit rate falls below the UE-AMBR value, the system will no longer throttle data.

There are bandwidth management controls that enable the PSBBN to allocate specified amounts of bandwidth to LTE dedicated guaranteed bit rate (GBR) bearers. GBR bearers are often used, for example, by streaming real-time audio and video applications. The bandwidth management controls for GBR bearers consist of a guaranteed bit rate (GBR) as well as a maximum bit rate (MBR) for each LTE bearer. The guaranteed bit rate value is the minimum bandwidth provided by PSBBN should the bearer be admitted to the LTE system. The admission process allocates enough bandwidth to assure delivery of data up to the value of the GBR. This bandwidth is available to the UE independent of the PSBBN congestion levels. The maximum bit rate (MBR) is the absolute maximum amount of bandwidth an LTE GBR bearer can utilize once it has been admitted. The MBR allows for additional bandwidth utilization above the GBR value assuming there are resources available in the PSBBN. Once the MBR bandwidth is exceeded, the PSBBN will throttle the excessive bandwidth usage. The GBR and MBR limits essentially create a minimum and maximum amount of bandwidth that can be used for a given GBR bearer. These GBR controls are only applicable to GBR bearers.

The combination of the controls described provides flexibility in allocation of bandwidth in the PSBBN. These controls can be set by the authorized agency administrator to meet the required needs of the responders who are utilizing bandwidth on the PSBBN.

C. Appendix C: Transport Priority Details

The priority attribute that is utilized to determine LTE EPS transport priority is the LTE assigned QCI for the LTE bearer (see section 2.3). The LTE QCI for the EPS bearer is chosen from the standards defined set of QCIs (3GPP TS 23.203). One means to specify transport architecture is to utilize the QCI and map the QCI to the EPS tunnel header Diffserv CodePoint (DSCP) in a manner such that the transport treatment at the DSCP layer is consistent with the priority of the LTE QCI. The mapping of the QCI to the DSCP is not specified in 3GPP standards, thus is operator configurable.

The use of DSCP is a means of prioritizing transport, mapping of the LTE QCI to the appropriate class and per hop behavior specified by the IETF. The following are recommendations that could be implemented to differentiate the EPC based bearers to provide end to end QoS based transport.

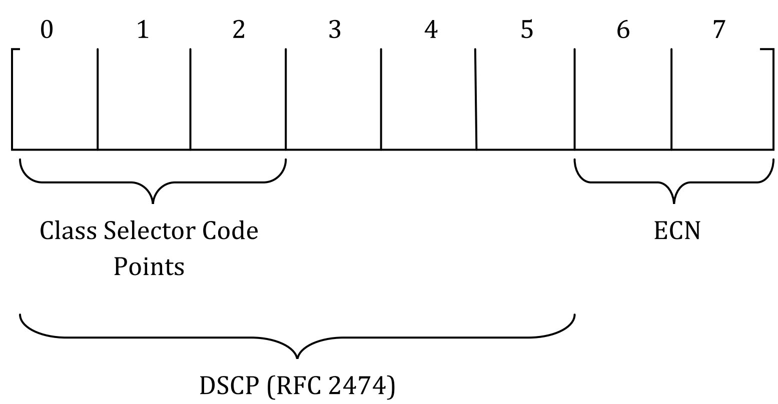
The Expedited Forwarding DSCP class provides transport prioritization that optimizes for low delay, loss and jitter. Voice services have requirements that are within these categories, thus recommended that the voice based QCI 1, as well as QCI 7 would be mapped to the EF DSCP class. The signaling QCI (QCI 5) could also be mapped to the EF DSCP class due to the importance of the signaling traffic carried over QCI 5 bearers.

The Assured Forwarding classes offer a range of performance attributes. Each AF class has 3 levels of packet drop precedence. The higher priority AF classes SHOULD be utilized for QCI transport associated with video and related services. This would map a high priority AF class (i.e. AF Class 4) to QCI 2 and QCI 3. For non-GBR video services, a lower AF class (i.e. AF Class 2) could be mapped to QCI 6. QCI 4 could be mapped to an intermediate AF Class (i.e. AF Class 3) due to the low packet loss rate.

The Best Effort DSCP class provides packet delivery that is provided by the network nodes after the other DSCP classes (i.e. EF, AF) have been satisfied. Thus, it would be consistent to map the BE DSCP class with best effort QCI(s). Based on the 3GPP definitions, QCI 8 and QCI 9 would be mapped to the BE DSCP class.

IETF DSCP Info

The DSCP is provisioned as part of the ToS IP header. The six most significant bits of the Type of Service (ToS) IP header byte are defined as the DSCP. These six DSCP bits are mapped to the Per Hop Behavior (PHB) classes or categories. Per hop behavior (PHB) describes what a Diffserv class should experience in terms of loss, delay, and jitter. A PHB determines how bandwidth is allocated, how traffic is restricted, and how packets are dropped during congestion.



The three most significant bits of the DSCP are used as class selector bits (CS), these bits are used to maintain backward compatibility with network UEs that use the ToS Precedence field, and as such DiffServ defines the Class Selector. The Class Selector codepoints are of the form 'xxx000'. The first three bits are the IP precedence bits. Each IP precedence value can be mapped into a DSCP class.

Class Selector Name	DSCP Value	IP Precedence	DSCP Class
CS7	56 [111000]	7	---
CS6	48 [110000]	6	---
CS5	40 [101000]	5	Expedited Forwarding
CS4	32 [100000]	4	Assured Forwarding 4
CS3	24 [011000]	3	Assured Forwarding 3
CS2	16 [010000]	2	Assured Forwarding 2
CS1	8 [001000]	1	Assured Forwarding 1
CS0	0 [000000]	0	Best Effort

Three PHBs are defined in DS based on the forwarding behavior required:

- Expedited Forwarding (EF) PHB—Class selector bits set to 101, optimal for low-loss, low-latency traffic
- Assured Forwarding (AF) PHB—Class selector bits set to 001, 010, 011, or 100, gives assurance of delivery under prescribed conditions
- Best-effort class—Class selector bits set to 000, typically best-effort traffic

The IETF defines Expedited Forwarding (EF) behavior as having characteristics of low delay, low loss and low jitter. These characteristics are suitable for voice, video and other real-time services.

The IETF defines the Assured Forwarding (AF) behaviors to provide assurance of delivery as long as the traffic does not exceed some subscribed rate. The Assured Forwarding standard specifies four guaranteed bandwidth classes and describes the treatment each should receive. It also specifies drop preference levels, resulting in a total of 12 possible AF classes. Traffic that exceeds the subscription rate faces a higher probability of being dropped if congestion occurs. The AF behavior group defines four separate AF classes (see table below). Within each class, packets are given a drop precedence (high, medium or low). The combination of classes and drop precedence results in twelve separate DSCP encodings. Should congestion occur between classes, the traffic in the higher class is given priority. If congestion occurs within a class, the packets with the higher drop precedence are discarded first.

Drop Precedence	Class AF1	Class AF2	Class AF3	Class AF4
Low Drop	AF11 (DSCP 10)	AF21 (DSCP 18)	AF31 (DSCP 26)	AF41 (DSCP 34)
Medium Drop	AF12 (DSCP 12)	AF22 (DSCP 20)	AF32 (DSCP 28)	AF42 (DSCP 36)
High Drop	AF13 (DSCP 14)	AF23 (DSCP 22)	AF33 (DSCP 30)	AF43 (DSCP 38)

The default PHB is used for traffic that does not meet the requirements of any of the other defined classes. The default PHB has best effort forwarding characteristics.

Differentiated Services is described and defined in the following RFCs:

- RFC 2474, Definition of the Differentiated Service Field (DS Field)
- RFC 2475, An Architecture for Differentiated Service
- RFC 2597, Assured Forwarding PHB Group
- RFC 2598, An Expedited Forwarding PHB
- RFC3168, The Addition of Explicit Congestion Notification (ECN) to IP