Project 25 Technology Interest Group White Paper:

P25 Trunking Control Channels

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P25 Background

Radio users around the world depend on P25 for their mission critical communications and interoperability among agencies during day-to-day operations and during emergencies.

The P25 standard was first established in October of 1989 and has an extensive history within the public safety community. While the P25 suite of standards includes a complete list of interfaces and standards, the Common Air Interface (CAI) is the "core" of interoperability and is the most widely deployed P25 interface. The CAI enables interoperability between: P25 radios in a direct radio-to-radio (talk around) mode; P25 radios and infrastructure in a single or multiple –site conventional configuration or system; and P25 radios and infrastructure in a trunked system configuration (also single or multiple-site), regardless of manufacturer.

The terms "FDMA" and "TDMA" are used throughout the remainder of this document. FDMA is an acronym for "Frequency Division Multiple Access" and TDMA is an acronym for "Time Division Multiple Access". When the term TDMA is used, it is referring to "two slot TDMA".

P25 Trunking

A P25 trunked system can be deployed with either FDMA or TDMA traffic channels or a mixture of FDMA and TDMA traffic channels. The FDMA CAI is designed to provide 12.5 kHz spectral efficiency and meet FCC (Federal Communications Commission) narrow-banding requirements, while the TDMA CAI is designed to provide 6.25 kHz "equivalent" spectral efficiency by providing two virtual channels within a 12.5 kHz channel. For TDMA, the two virtual channels are commonly referred to as "TDMA slots". When a 12.5 kHz channel is operating in TDMA mode, the infrastructure is using both slots for outbound signaling. Depending on how the TDMA channel is being used, radios are instructed to use one or the other slot for inbound signaling (radio to infrastructure) and radios will listen to one or both slots for outbound signaling (infrastructure to radio).

Prior to the development of the TDMA control channel, both FDMA and TDMA trunking traffic channels utilized an FDMA 12.5 kHz control channel. The advantages of this approach include:

- Interoperability: The standardization of the trunking control channel enables and promotes interoperability among different manufacturers' trunked radio subscribers.
- Migration: A common trunking control channel for both FDMA and TDMA trunked subscribers allows user agencies the flexibility of migrating their system over time from FDMA to TDMA by gradually adding TDMA capable devices as their budget allows.
- Hybrid System Support: The common control channel can be used to support hybrid systems with multiple sites and/or simulcast cells, where different sites/cells can support multiple voice and/or traffic channels that may be configured as FDMA or TDMA based

on agency traffic load or requirements. Additionally, hybrid sites/cells can be configured which support both FDMA and TDMA subscriber radios where calls are dynamically assigned based on FDMA/TDMA capability of the subscribers involved potentially on a site by site basis.

P25 TDMA Control Channel

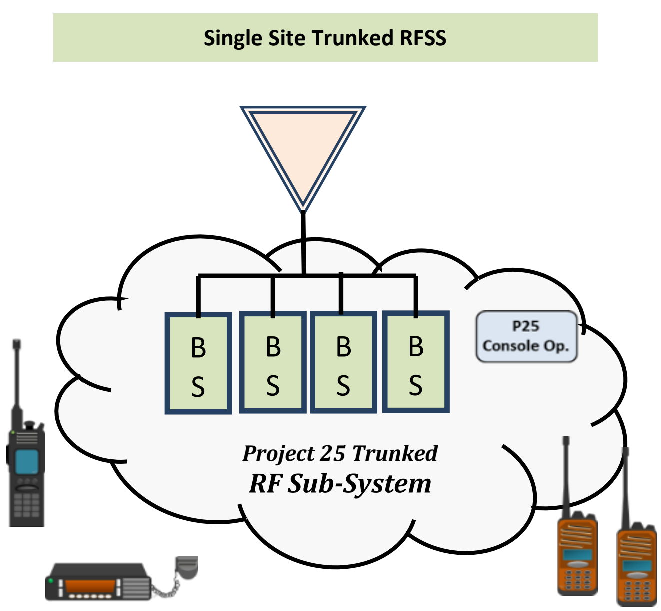
A new addition to the P25 suite of standards defines a TDMA control channel for P25 trunking operation. Similar to the FDMA trunking control channel, the TDMA control channel includes an inbound (radio to infrastructure) channel which is used for individual or group service requests for voice, data or supplementary service. It also includes an outbound (infrastructure to radio) channel which broadcasts system information, control signaling, and provides call assignments.

Overview

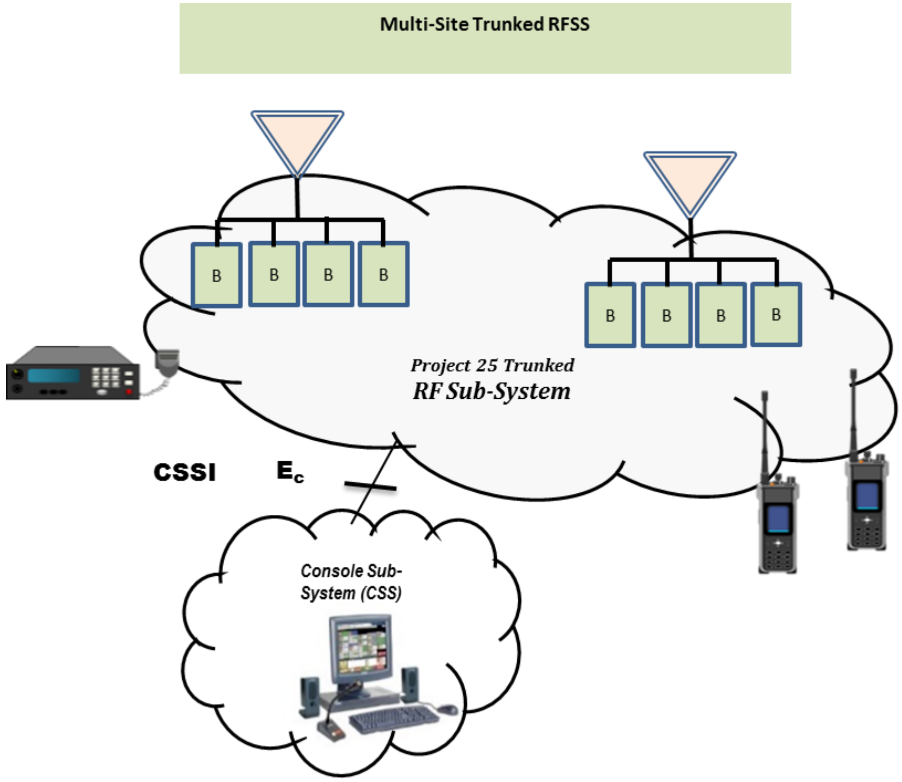
The TDMA control channel supports the same functionality as the FDMA control channel. However, with the use of the TDMA control channel, a single 12.5 kHz channel supports two virtual channels and can be configured to utilize one or both virtual channels for inbound/outbound signaling.

A P25 trunked system with a TDMA control channel can be deployed in the same type of configurations as current trunked systems, such as:

Single Site

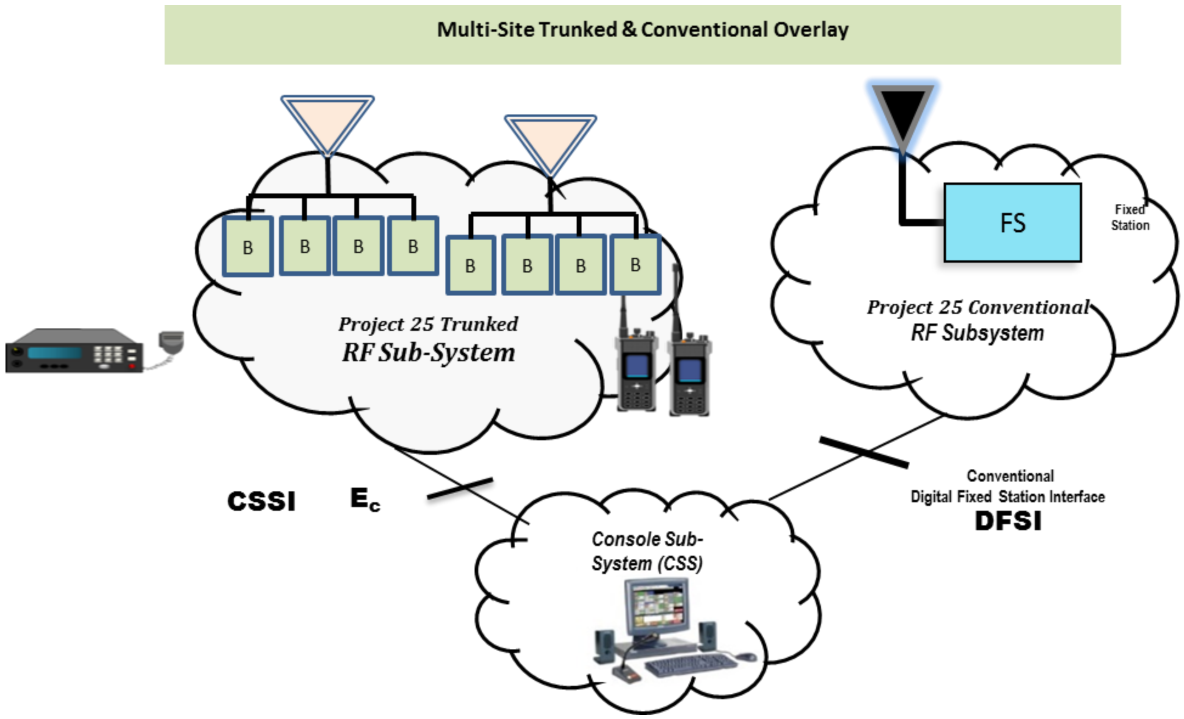


Multi-Site (Multi-Cast or Simulcast[1])



Multi-Site Trunked with Conventional Overlay

[1] A simulcast or voting subsystem involves a collection of sites working on common frequencies that together, act as a subsystem. This subsystem acts like a single trunking site but has a much larger coverage area than a single trunking site.



A single logical TDMA control channel may designate either virtual channel (slot) of the two-slot TDMA physical radio channel as a control channel. In this case, control channel signaling is conveyed between the infrastructure and the radio population at the Site on one of the virtual channels and the other virtual channel is available for use as a traffic channel.

A dual logical TDMA control channel designates both virtual channels (slots) of a two-slot TDMA physical radio channel as control channels. In this case, control channel signaling is conveyed between the infrastructure and the radio population at the Site on both virtual channels. The radio monitors both outbound virtual channels for outbound control channel signaling and uses the first inbound virtual channel available for inbound control channel signaling.

The protocol for outbound two-slot TDMA physical radio channels includes signaling information between each slot that is used by receiving radios. The signaling information informs listening radios whether the two-slot TDMA physical radio channel is being used for voice signaling or control channel signaling. If the indication is for control channel signaling, additional information is provided to inform the radio of single logical control channel or dual logical control channel operation. If single logical control channel operation is indicated, additional information is provided that informs the radio which virtual channel is being used for control channel signaling.

Composite TDMA control channel operation is a special case of single logical TDMA control channel. A TDMA call is granted that converts the logical control channel to a traffic channel. The logical control channel is reestablished when a logical TDMA channel capable of acting as a control channel becomes available.

Benefits of the TDMA Control Channel

The TDMA control channel can provide benefits to an agency/system manager once all of the radios in the system support TDMA operation and are also capable of supporting the TDMA control channel. Several example scenarios are envisioned where the TDMA control channel can benefit P25 users.

Perhaps the most obvious benefit is realized in low density user situations where a relatively low amount of call traffic is expected and only a single 12.5 kHz physical channel is available. In this situation, use of the single logical TDMA control channel allows the system designer to configure the site with dedicated control and traffic functionality while only provisioning a single 12.5 kHz channel. In this configuration, a single TDMA radio channel would utilize one virtual channel for control signaling and one virtual channel for voice signaling.

For these single RF channel situations, the "dual-function" 12.5 kHz TDMA channel described above has advantages over the "single function" 12.5 kHz FDMA composite control channel previously defined in the P25 suite of standards. A 12.5 kHz FDMA composite control channel operates either in a state for trunking control or as a traffic channel, and while operating in traffic channel mode (when supporting a call) would not be capable of providing control signaling or supporting supplementary services. With the single logical TDMA control channel, a single 12.5 kHz physical channel can support a single voice call while maintaining the presence of the dedicated control channel functionality. This allows for call request queuing and continuous control signaling to support supplementary services such as emergency alarms while also supporting a single voice call.

In more common situations where more than one 12.5 kHz physical channel is available at the site, transition to the TDMA control channel allows agencies to instantly improve spectrum efficiency and traffic capacity without increasing the number of physical channels. For example, a four-channel site with the FDMA control channel and three TDMA traffic channels can support six simultaneous talk-paths. However, with a transition to the TDMA control channel in a single slot, the system would now be capable of supporting seven talk-paths – an increase in virtual resources of 17% without the addition of any physical channels. This increase will provide greater traffic capacity for the system/site and reduce the effect of busies and call queuing.

Another benefit can be realized in high density situations where a relatively high amount of traffic is expected and many traffic channels are available at the Site. In high traffic volume situations, a dual logical TDMA control channel can provide an efficient means of supporting larger amounts of traffic using a single two-slot TDMA physical radio channel. This may eliminate the need for multiple FDMA control channels at high density Sites.

Transitioning to the TDMA Control Channel

For system managers with existing P25 trunking systems, the transition to a TDMA control channel requires planning. The system infrastructure, including the base stations and core equipment will need to have the necessary software revision to support the feature.

An important consideration is that, under typical conditions, a Site which utilizes the TDMA control channel will only support TDMA capable subscriber radios which also include the TDMA control channel capability. However, with radio equipment capable of supporting both FDMA and TDMA traffic and control channels, a site with a TDMA control channel can still support FDMA traffic call assignments (voice or data) when multi-site calls demand

FDMA for interoperability with FDMA only radios. Note that when these multi-site calls do include FDMA only radios, vocoder parameter conversion (also referred to as "transcoding") may be used. This allows a multi-site call to be assigned as FDMA at some sites and TDMA at some sites.

Therefore, it is essential that the system manager performs a thorough inventory of its subscriber base and roaming requirements for all agencies supported by the system, including visiting radios from interoperability and roaming partners. Failure to consider all potential users of the system may result in unforeseen interoperability issues.

Perhaps a best practice approach would be for a system manager/agency to determine how they plan to take advantage of the TDMA control channel capability; then perform the inventory of the system infrastructure and subscriber equipment to be supported in that scenario; confirm or plan for upgrade to the required TDMA control channel software revision in both infrastructure and radio equipment; and then develop the equipment upgrade and transition plan and schedule.

Conclusion

The P25 suite of standards is evolving and continuing to grow as technology and user requirements evolve. The standardization of the TDMA control channel will enable multiple manufacturers to support this capability with interoperable equipment. Additionally, the TDMA control channel will provide another option for system managers and user agencies to effectively support their users and to improve the spectrum efficiency of their network both low density and high density situations.