Technical Overview of 1xEV-DV

White Paper

Abstract

This document is a white paper over viewing the technical and product impacts of 1xEV-DV.

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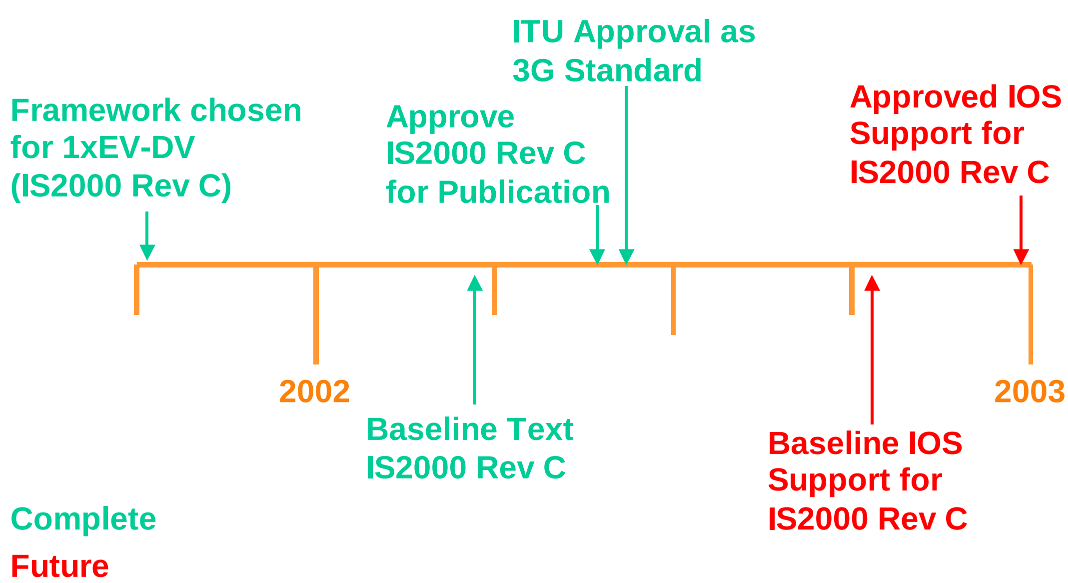
Table of Contents

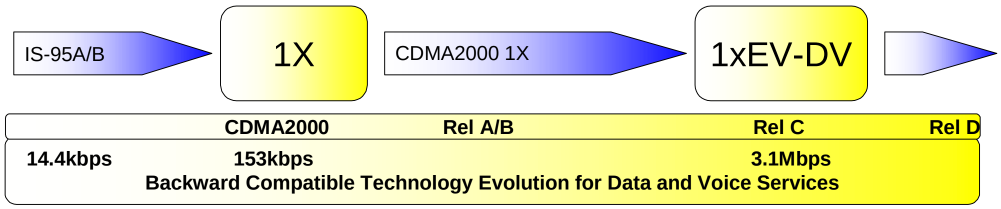
1. Introduction

As CDMA2000 1X is being deployed in various markets around the world, the evolution of 1X is actively being developed within the industry. 1xEV-DV is being developed as the natural evolution of CDMA enabling operators to smoothly evolve their networks and provide continuity for their existing services. Key services such as support for voice and data on the same CDMA carrier will continue to be supported while allowing operators to leverage their investments in CDMA2000 1X.

As of this date, 3GPP2 TSG-C has approved CDMA2000 Release C (commonly referred to as 1xEV-DV) for TIA publication. In addition, the ITU has approved 1xEV-DV as a world recognized 3G standard. 3GPP2 TSG-A has also started discussing 1xEV-DV and is working towards an IOS release containing 1xEV-DV specifications this year. The following diagram summarizes the current schedule for 3GPP2's 1xEV-DV efforts:



With the completion of 1xEV-DV specifications – both in the CDMA2000 air interface standards and the IOS standards by the end of 2002, it is expected that 1xEV-DV commercial products will begin to be rolled out across various markets within 2-3 years. The following diagram summarizes the evolution of CDMA technology. As an evolution of CDMA2000 1X, 1xEV-DV is backward compatible to IS-95A/B and CDMA2000 1X and will enable a simple migration to 1xEV-DV from 1X networks while preserving existing services offered by operators, including voice and data services on the same carrier, and simultaneous voice and data.



The CDMA industry's extensive efforts in development of 1xEV-DV technology combined with feedback from operators world-wide have led to the understanding that the 1xEV-DV product must provide these key technology benefits:

- Peak data rate of 3.1 Mbps per sector as specified in IS2000 Release C
- Support of both real-time and non real-time data services
- Seamless backward compatibility with IS-95A/B and CDMA2000 1X
- Support of voice and data in the same carrier
- Natural, standardized evolution of CDMA technology
- Enable unique features for CDMA operators

To meet the market needs for 1xEV-DV deployment, it is required that both TSG-C and TSG-A be stabilized by the end of 2002. CDMA2000 Rel C was published in May 2002 and currently TSG-C is completing updates to IS-707 for support of 1xEV-DV. Other TSG-C performance and test specifications will follow. TSG-A is adding the necessary changes in the existing IOS standards & architecture to support 1xEV-DV. Since 1xEV-DV is predominantly a new High-Speed Packet Data Channel in CDMA2000, the IOS changes are fairly contained.

The ultimate goal with 1xEV-DV technology and products is to enable CDMA operators to improve their competitiveness in offering new value-added services leading to improved return on investments. This is to be achieved through key benefits offered by 1xEV-DV:

- Leveraging operators' investments in CDMA2000 1X by reusing 1X network components
- Backward compatibility minimizes replacement of equipment such as network equipment and subscriber handsets
- Provide continuity for current IS-95A/B and 1X services, including Simultaneous Voice and Data
- 1xEV-DV extends CDMA2000 1X capabilities to enable new services for voice, data, and multimedia

2. 1xEV-DV Technical Overview

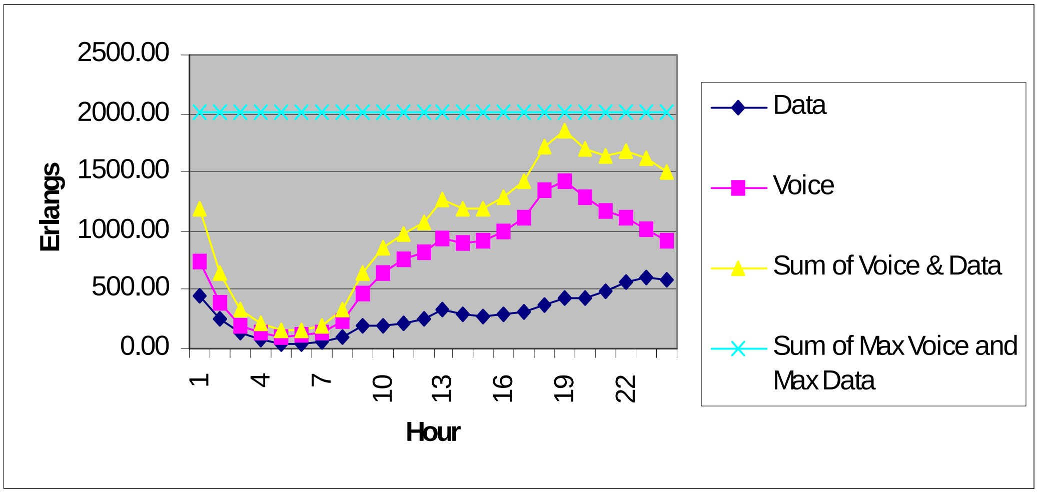
The 1xEV-DV enhancements add new capabilities to the CDMA2000 air interface while reusing many CDMA2000 capabilities. This section provides a technical overview of the 1xEV-DV air interface by examining the new features, the reuse from CDMA2000 and example call flows.

2.1. 1xEV-DV Requirements and Architecture

1xEV-DV introduces a number of new features to the CDMA2000 air interface family. The key features and enhancements are:

1. **Higher Forward Link Capacity.** 1xEV-DV incorporates a number of features that combine to provide an increase in forward link data rates up to 3.1 Mbps and average sector throughputs of 1 Mbps. These features include Adaptive Modulation and Coding schemes (AMC), applying Hybrid Automatic Repeat reQuest (HARQ) to the Physical Layer frame, defining a new forward link traffic channel called the Forward Packet Data Channel (F-PDCH) and providing both Time Division Multiplexing (TDM) and Code Division Multiplexing (CDM) treatments to the data transmitted on this channel. Each of these features is discussed in more detail in section 2.2. The addition of these features provides both the operator and the subscriber with the benefit of higher rate data services. With the addition of 1xEV-DV, subscribers now have access to services that are not available in earlier CDMA technologies. This also provides the operator with increased opportunities for higher revenue from their subscribers.

2. **Voice Service and Concurrent Voice/Data Support.** The 1xEV-DV air interface supports both voice and data services in both the forward and reverse links. This provides the operator with a very flexible method for using spectrum. With this feature, the operator can share spectrum between voice and data services, providing simultaneous voice and data services. This capability provides the operator with a very flexible method of controlling how spectrum is allocated. The following figure demonstrates this point. By taking advantage of the different usage patterns of voice and data, an operator that shares voice and data on a single carrier can optimize spectrum utilization.



- Usage statistics from commercial network show that voice and data busy hours occur at different times of the day
- Example: Voice and data on separate carriers generates a maximum of 2020 erlangs (599 data and 1421 voice - Sum of Max Voice and Max Data) compared to 1856 erlangs on same carrier (Max of Sum of Voice & Data) for a savings of over 9% on channel resources.

Figure 1. ***Spectrum Usage of Voice and Data***

3. **Multiple Concurrent Traffic Types**. The 1xEV-DV specification supports both the multiplexing of signaling and user data over the F-PDCH and multiple concurrent data sessions. This provides a benefit to both the operator and subscriber since this capability supports Personal Computer (PC) based applications. The subscriber can now operate multiple PC applications simultaneously. The operator can gain the revenue from these multiple applications without allocating a fundamental channel to each application.

4. **Backward Compatibility with CDMA2000.** One of the goals of the 1xEV-DV specifications is providing smooth support for voice and legacy services. This is accomplished by reusing existing CDMA2000 standards wherever possible. Examples of this reuse include reusing the 1X reverse link channels, IS-2000 MAC and signaling layer procedures, support for handoffs between 1xEV-DV radio channels and other CDMA2000 radio channels and interoperability based on IOS. This benefits the operator by providing a smooth migration path from their deployed 1X infrastructure. This feature also minimizes impacts to existing infrastructure as the operator upgrades their network to 1xEV-DV. Finally, the subscriber is guaranteed of owning a mobile device that can support both 1X and 1xEV-DV air interfaces, providing a single terminal that can operate over the operator's entire network. The following figure demonstrates this point. An operator has the option of overlaying

1xEV-DV on the same carrier as supports IS-95A/B or 1X. This allows the operator to control the migration and customize spectrum usage.

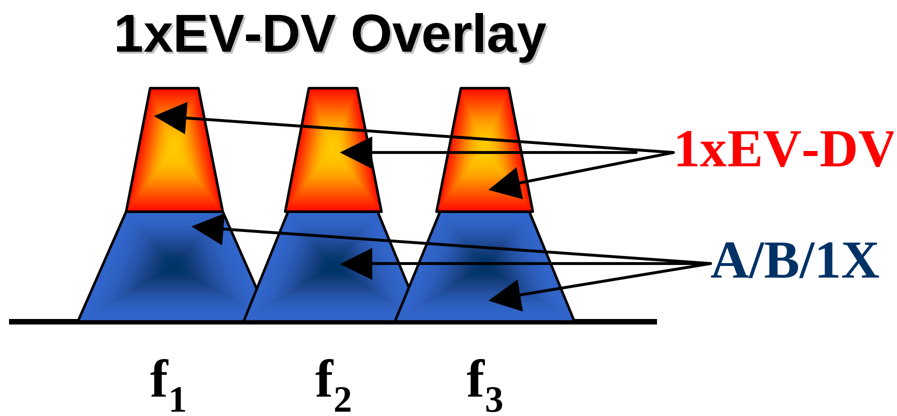


Figure 2. ***1xEV-DV Overlay***

5. **Efficient support of all data services (e.g., VoIP)**. 1xEV-DV allows the flexibility of both TDM and CDM scheduling (TDM/CDM), favoring TDM where TDM works the best (e.g., services which are akin to the infinite queue best-effort data model, such as ftp), and allowing for CDM to efficiently serve data for other services (e.g., WAP, VoIP, streaming video, etc.). TDM/CDM multiplexing is a powerful feature in 1xEV-DV and is unique to 1xEV-DV. It maximizes system throughput by providing optimal modulation and coding rate assignments on a non-discriminatory basis to all services, thereby providing the operator with the flexibility necessary in a dynamic market environment.

In considering these requirements, TSG-C made modifications to the 1X Air Interface Layer Architecture. The resulting architecture is shown in **Figure 3. cdma2000 Rev C *Air Interface Layer Architecture***. In the 1xEV-DV modifications, a new functional entity, the F-PDCH Control Function was created. Since it contains functions traditionally allocated to both the Physical and MAC layers (adaptive modulation and coding, Hybrid ARQ), it was created as an intermediate layer. The detailed specification of functions allocated to the F-PDCH Control Function is given in reference [1].

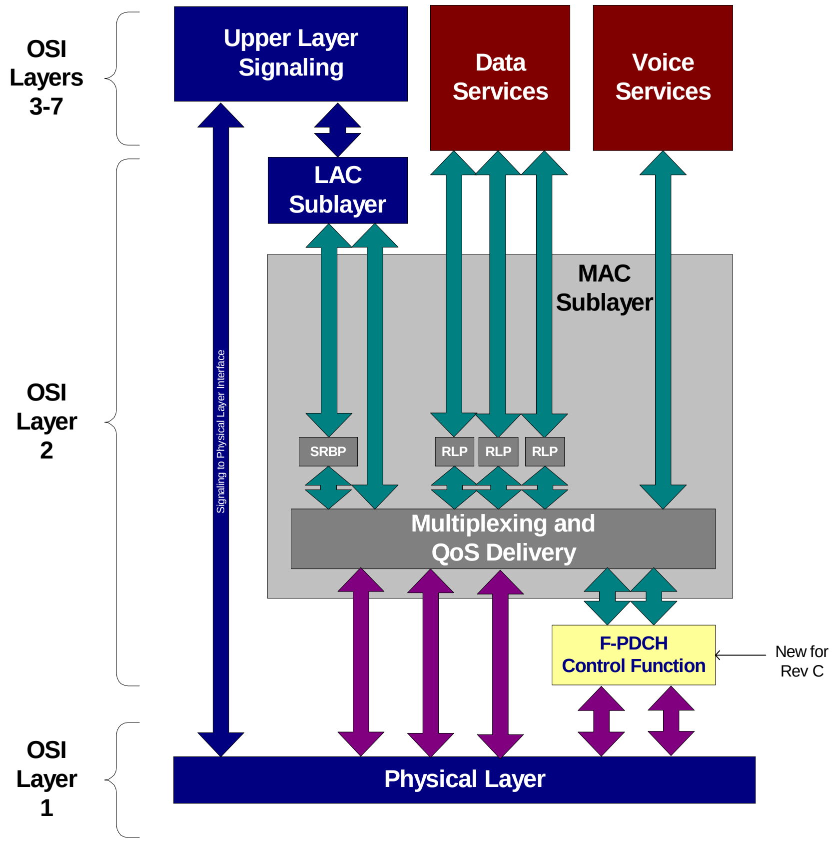


Figure 3. ***cdma2000 Rev C Air Interface Layer Architecture***

2.2. 1xEV-DV Features

Meeting the requirements and architecture required the invention of new features for 1xEV-DV. These new features include new channels, an adaptive modulation and coding scheme, addition of ARQ to the Physical Layer and Cell Selection. Each of these will now be considered. For more details, the reader is directed to reference [1]. When taken together, these features provide a very powerful tool for operators who want to provide data services to their subscribers while greatly increasing air interface capacity. These features allow the operator to plan migration strategies that optimize their RF utilization while providing subscribers with an impressive selection of data rates for revenue enhancing data services.

2.2.1. New Physical Channels

The 1xEV-DV specifications added a new traffic channel and three new control channels. These channels are summarized in **Table 1. New 1xEV-DV Channels**. In the forward link the new traffic channel is the Forward Packet Data Channel (F-PDCH) and the new control channel is the Forward Packet Data Control Channel (F-PDCCH). In the reverse link only two new control channels are defined. They are the Reverse Channel Quality Indicator Channel (R-CQICH) and

Reverse Acknowledgment Channel (R-ACKCH). No new traffic channel exists in the reverse link for this release of 1xEV-DV. The 1X traffic channels (R-FCH, R-DCCH and R-SCH) are reused for 1xEV-DV.

The F-PDCH is the new traffic channel added to CDMA2000 for providing the 1xEV-DV data rates. The Adaptive Modulation and Coding techniques, the TDM/CDM multiplexing techniques and the Hybrid ARQ protocol are all applied to information transmitted in the channel to achieve the high data rates[1]. The F-PDCCH channel is a forward link control channel and provides the mobile with the information it needs to correctly identify data intended for it on the F-PDCH. The information transmitted on the F-PDCCH that the mobile uses for decoding its information on the F-PDCH is: the MAC-ID, the F-PDCH packet size, the Number of Slots per Sub-packet and the Last Walsh Code Index. The MAC-ID is an 8-bit identifier known by the mobile and the Base Station that identifies the data on the F-PDCH as belonging to that mobile. The MAC-ID is established as part of call setup and remains associated with the mobile for the duration of the call (see section 2.2.5 for more details). The F-PDCH packet size field indicates the size of the F-PDCH packet being transmitted and the Number of Slots field indicates how many TDM slots are used for the transmission (see section 2.2.2 for more details). The Last Walsh Code Index is used by the mobile to determine the Walsh cover used in the data transmission (see section 2.2.5 for more details). This enables Code Division Multiplexing on the F-PDCH. There are two F-PDCCH channels supported in the forward link. These channels are time synchronized with the F-PDCH so that the mobile can easily use the F-PDCCH information to properly decode and demodulate the F-PDCH information (see section 2.2.5 for an example and further discussion).

There are two new control channels added to the reverse link. They are the Reverse Channel Quality Indicator Channel (R-CQICH) and Reverse Acknowledgment Channel (R-ACKCH). The R-CQICH is used by the mobile station and indicates to the base station the channel quality measurements of the best serving sector. The mobile station informs the base station whether or not the F-PDCH packet was successfully decoded by using the R-ACKCH.

The main benefit of these new channels is the high data rates now supported. This channel architecture also provides the operator with a powerful migration tool. Since 1xEV-DV channels are integrated with existing CDMA2000 channels, the operator can deploy 1xEV-DV in areas of CDMA2000 coverage where data services needing a higher data rate are required.

New 1xEV-DV Channels	Channel Description
Forward Packet Data Channel (F-PDCH)	Main packet channel. One channel per sector. Users separated by TDM and CDM. Carries Data and L3 Signaling.

[1] Adaptive Modulation and Coding is discussed in section 2.2.2, TDM/CDM multiplexing is discussed in section 2.2.5 and Hybrid ARQ is discussed in section 2.2.3.

Forward Packet Data Control Channel (F-PDCCH)	Sends demodulation, decoding and ARQ information to specific mobile. Two channels per sector.
Reverse Acknowledgment Channel (R-ACKCH)	ACK/NAK feedback for Hybrid ARQ.
Reverse Channel Quality Indicator Channel (R-CQICH)	Provides channel quality feedback to base station. Feedback data is used as an input to forward link modulation, coding and scheduling. Mobile indicates selection of serving sector by spreading cover.

Table 1. ***New 1xEV-DV Channels***

2.2.2. Adaptive Modulation and Coding

In 1xEV-DV, the forward link Modulation and Coding are varied in real time to adapt to the RF environment. It is a link adaptation scheme where the base station assigns users the best modulation and coding rate for the instantaneous channel conditions. The addition of Adaptive Modulation and Coding provides both the operator and the subscriber with the benefit of higher rate data services. With the addition of 1xEV-DV, subscribers now have access to services that are not available in earlier CDMA technologies. This is achieved by varying the RF frame duration, the number of bits per RF frame and the coding algorithm. The RF frame duration is 1.25, 2.5 or 5 milliseconds. The bits per RF frame varies between 408 and 3864 bits and the modulation choices are QPSK, 8-PSK and 16-QAM. The scheduling algorithm now takes advantage of the RF environment to maximize the RF utilization by making the optimal choice of RF frame duration, bits per RF frame and modulation.

Table 2. Forward Packet Data Channel Data Rates shows how packet size and RF frame duration are combined to result in varying data rates. The “Number of Slots per Sub-packet” represents the RF frame duration (1 slot = 1.25 milliseconds). All of the RF frame durations and the F-PDCH packet sizes are mandatory in IS-2000 Release C. This strategy of varying the RF frame duration, RF frame size and modulation choices has been borrowed from 1xEV-DO and has been successfully demonstrated by a number of 1xEV-DO vendors.

		Number of Slots per Sub-packet		
		1	2	4
F-PDCH Packet Size (Bits)	408	326.4 kbps	163.2 kbps	81.6 kbps
	792	633.6 kbps	316.8 kbps	158.4 kbps
	1560	1248.0 kbps	624.0 kbps	312.0 kbps
	2328	1862.4 kbps	931.2 kbps	465.6 kbps

	3096	2476.8 kbps	1238.4 kbps	619.2 kbps
	3864	3091.2 kbps	1545.6 kbps	772.8 kbps

Table 2. Forward Packet Data Channel Data Rates

The benefit of this feature is that it provides flexible mechanism for achieving data rates up to 3.1 Mbps. There is also a rich set of data rates available for the Base Station to choose. This allows the Base Station to make the most efficient use of resources. Increasing modulation complexity and reducing code rate are well known techniques for increasing the throughput of a communications channel. The cost of these techniques is increased sensitivity to channel degradations. In traditional radio systems, a fixed coding rate and modulation are chosen based on a compromise between data throughput and robustness to widely varying channel degradations. 1xEV-DV avoids the tradeoff by using a feedback approach to continually choose the best combination of modulation and coding based on the instantaneous radio environment between the base and mobile stations. This maximizes the link throughput by choosing high modulation orders and low coding rates for favorable radio conditions, while choosing more conservative modulation and coding rates for less favorable radio conditions so that retransmissions are minimized.

2.2.3. Hybrid ARQ

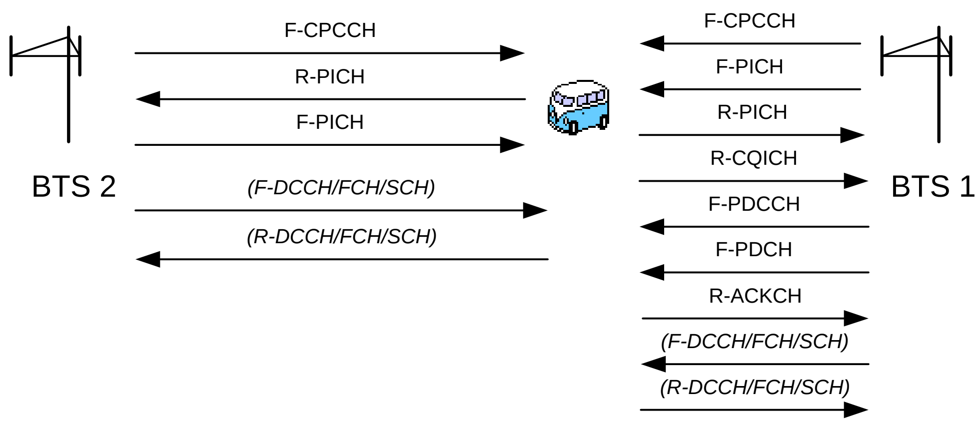
In 1xEV-DV, fast retransmission of frames received in error is critical to maintaining high bandwidth. So, ARQ has migrated from the MAC layer to the physical layer. Hybrid ARQ improves throughput by combining (rather than discarding) failed transmission attempts with the current attempt, effectively creating a more powerful code. Hybrid ARQ also enables fast AMC by making the initial modulation and code rate selection process tolerant to selection errors. The two fundamental forms of Hybrid ARQ are Chase combining and incremental redundancy (IR). In Chase combining, each retransmission repeats the first transmission or part of it. In IR, each retransmission provides new code bits from the mother code to build a lower rate code. While Chase combining is sufficient to make AMC robust, IR offers the potential for better performance with high initial code rates and FER operating points (i.e., a greater probability that a transmission beyond the first will be needed), at the cost of additional memory and decoding complexity. The consensus in the 3G CDMA standards bodies is to explicitly define and allow IR, while retaining the ability of Chase-like operation as a subset of IR (i.e., repeating part or all of a first transmission rather than sending new parity bits is allowed). Hybrid ARQ both improves throughput and enables fast adaptive modulation and coding by making the initial modulation and code rate selection process tolerant to selection errors.

2.2.4. Cell Selection

In Cell Selection, the mobile station selects one base station from its active set to serve the forward link. The selection is based on the RF quality measurements made by the mobile. Since the mobile is selecting the base station with the best RF characteristics, there is no soft handoff for the F-PDCH or the supporting forward link control channels (the F-PDCCH). Cell section does require the base stations to synchronize the F-PDCH data stream, since it is possible that the mobile will have channels belonging to multiple base stations in its active set. **Figure 4. *Cell Selection*** shows an example of cell selection. In the figure, the mobile monitors the pilot channel of both BTS 1 and BTS 2. The mobile, determining that the channel quality is better from BTS 2, selects BTS 2 for F-PDCH traffic. It indicates this selection via the R-CQICH. The infrastructure receives this indication and transmits the 1xEV-DV forward link channels via BTS 2.

This diagram also shows that cell selection operates independently of soft handoff, since soft handoff continues to operate for CDMA2000 channels. Soft handoff is still used only with all 1X traffic channels (F/R-FCH, F/R-DCCH and F/R-SCH). Cell selection is used with the 1xEV-DV traffic channel (F-PDCH). So, for example, in a simultaneous voice and data call where the voice traffic uses the FCH and the data traffic uses the F-PDCH, the voice traffic would still use soft handoff while the data traffic would use cell selection.

Cell selection provides a significant infrastructure savings compared to the soft handoff techniques employed in CDMA2000. By using cell selection, operators are not required to backhaul the same multi-megabit traffic to multiple BTS sites or to drastically reduce the mobile's active set to one BTS site. Cell selection also utilizes the RF link more efficiently. With the high spreading rates used in the F-PDCH, interference is reduced by not utilizing soft handoff on the F-PDCH.



- Mobile monitors pilot channel (F-PICH) from both BTS 1 and BTS 2. Mobile indicates selection of BTS 1 via Walsh cover on R-CQICH, and provides information on channel quality to BTS 1 via R-CQICH data. Only BTS 1 transmits F-PDCCH and F-PDCH to mobile (based on BTS 1 scheduling decisions).
- Diagram shows fundamental and supplemental channels in soft-handoff.
- Benefit: Conserves RF capacity and backhaul bandwidth

Figure 4. *Cell Selection*

2.2.5. Flexible TDM/CDM Multiplexing

It is important that 1xEV-DV support all services, whether the services use large packets (e.g., FTP) or small packets (e.g., location services or voice). It was important to the developers of the 1xEV-DV specifications that all services use the RF channels efficiently. This led to the inclusion of both TDM and CDM into the 1xEV-DV specifications.

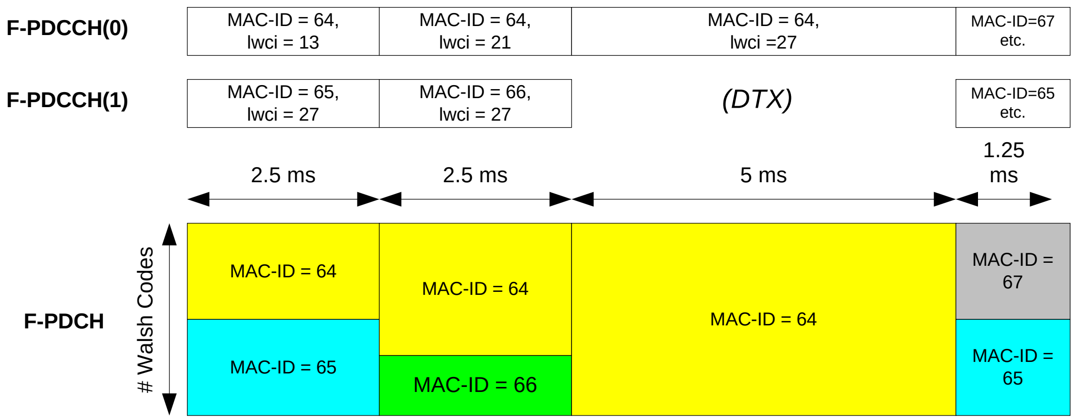
CDM was a natural choice for a CDMA evolution, but TDM made a great deal of sense for fat-pipe shared channel scheduling. An initial approach called for allowing both TDM and CDM scheduling (TDM/CDM), which favors TDM where TDM works the best (e.g., file transfer services) and allowing CDM when frame fill efficiency is needed (e.g., many mobiles transferring small data packets).

TDM and CDM multiplexing allows the selection of both the number of timeslots and the number of Walsh codes allocated to a user. This feature is illustrated in **Figure 5. TDM/CDM Multiplexing**. In this example, four users share the F-PDCH. This figure shows three key capabilities of TDM/CDM multiplexing:

1. Scheduling of multiple timeslots. This figure demonstrates how 4 users are allocated various numbers of timeslots. In this example, one user (MAC-ID 64) is allocated eight 1.25 millisecond timeslots while another user (MAC-ID 65) is initially allocated two 1.25 millisecond timeslots and then one 1.25 millisecond timeslot 7.5 ms later.

2. Sharing the Walsh code space among multiple users. This figure demonstrates how the Walsh code space is shared between multiple users at the same time. It also shows that this allocation is dynamic, as the Walsh code allocation varies between four users (represented by MAC-ID 64, MAC-ID 65, MAC-ID 66 and MAC-ID 67).

3. Allocating the entire F-PDCH to a single user. The entire F-PDCH can also be allocated to a single user. The decision to allocate the entire F-PDCH is done by the F-PDCH scheduler residing in the BSS and is driven by the priority of the user's service and the amount of data that needs to be transmitted to the user.



- Combined time-domain (TDM) and code-domain (CDM) multiplexing
- Control channels {F-PDCCH(0) and F-PDCCH(1)} identify scheduled mobiles and portion of F-PDCH assigned to each scheduled mobile
- Benefits: Increases efficiency of small data transfers (e.g. WAP), Enables real-time applications with increased scheduling flexibility

Figure 5. *TDM/CDM Multiplexing*

TDM/CDM multiplexing is an extremely powerful feature in 1xEV-DV and is unique to 1xEV-DV. The CDM feature provides the opportunity to allocate the entire F-PDCH to a single user or share it among multiple users. The TDM feature provides the opportunity to schedule the F-PDCH resource to users based on available data. It also guarantees that the F-PDCH resource is shared among all the users who request it.

An example of how resources are shared among voice and data users is shown in

Figure 6. Walsh Code *Tree*. In the 1xEV-DV specifications, 88% of the Walsh codes are available for 1xEV-DV channels with the remaining codes allocated to 1X channels. However, since the 1xEV-DV channels share the Walsh Codes with 1X channels, the 1xEV-DV code space can be reduced and the freed codes allocated to 1X calls.

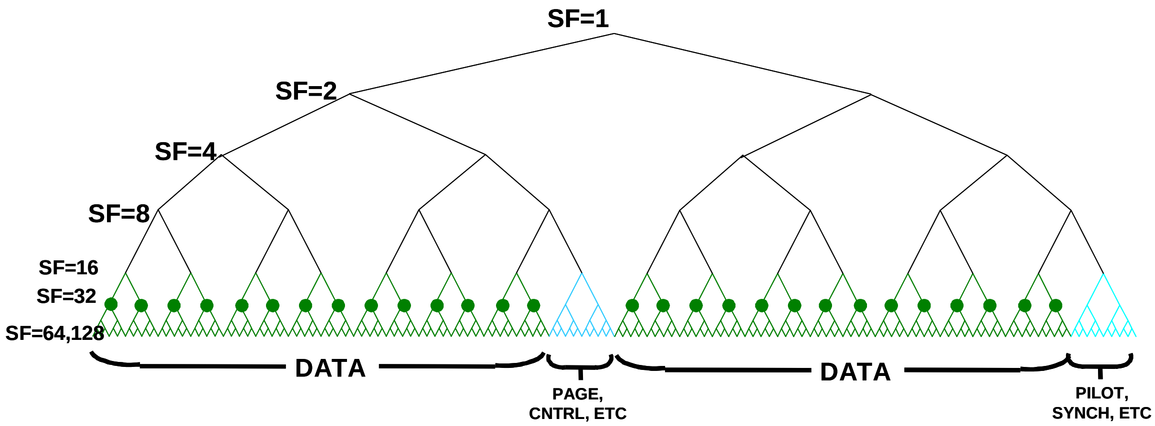


Figure 6. *Walsh Code Tree*

The figure shows the example where 28 Walsh Codes (at Spreading Factor 32) are allocated to the F-PDCH (the Walsh Codes identified as DATA). The remaining Walsh codes are available for control channels. This figure shows that the carrier is providing the maximum 1xEV-DV data rate (3.1 Mbps). The allocation of these 28 codes to the F-PDCH is reduced to support 1X services. So, for example, an operator who needs to allocate 50% of the carrier for voice services and the remaining portion for data services would see the Walsh codes allocated to 1xEV-DV reduced in half. This reduces the maximum data rate for 1xEV-DV to 1.55 Mbps while providing voice services.

The key benefit to the operator is adaptive allocation of resources. As voice call traffic increases, the Walsh codes allocated to the F-PDCH can be reallocated to voice calls. The BSS adapts Walsh code usage to existing traffic patterns so that when data traffic dominates, the majority of the Walsh codes are allocated to data. However, as voice services grow, the Walsh codes can be allocated to voice services automatically. This provides the operator with mechanisms for adapting their RF allocation to the changing voice and data traffic patterns that they need to support throughout the day.

2.2.6. Small Packet Support

1xEV-DV uses fast adaptive modulation and coding (AMC) combined with hybrid ARQ (HARQ) to efficiently serve both data and legacy (e.g., voice) services on a single carrier. Fast AMC is a link adaptation scheme where the base station assigns users the best modulation and coding rate for the instantaneous channel conditions, and hybrid ARQ (HARQ) both improves throughput and enables fast adaptive modulation and coding (AMC) by making the initial modulation and code rate selection process tolerant to selection errors. By serving each user the highest data rate their instantaneous channel conditions allow, overall system throughput is greatly improved.

Within the 3G CDMA evolution standards bodies, perhaps the biggest area of debate was the multiple access method to use in conjunction with the AMC and HARQ. CDM is a natural choice for a CDMA evolution, but TDM makes a great deal of sense for fat-pipe shared channel scheduling. In theory, a fat-pipe scheduler can rapidly satisfy a user, and then quickly move to another user. In practice, it is difficult to both provide precise portions and to move the fat-pipe quickly to another user without wasting resources. It is therefore relatively easy to make TDM work with services that require lots of data over longer periods of time, such as with the infinite queue best-effort data model or ftp. When the fat-pipe scheduler has to be more nimble and precise, such as with WAP, VoIP, streaming video, and other services, problems can arise. The TDM/CDM 1xEV-DV system maximizes system throughput by providing optimal modulation and coding rate assignments to all services while maintaining frame fill efficiency. As shown in Figure 7, a small packet may receive a few of the Walsh codes, and the remaining Walsh codes can be used by another user, improving overall system capacity.

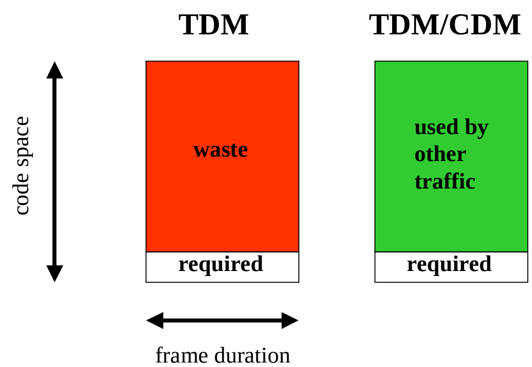


Figure 7. ***Example of TDM-only and TDM/CDM with small packets***

A system must be able to provide an appropriate modulation and coding rate (information bits per symbol) to all desired services in order to achieve promised system capacity gains. It is especially important to provide a proper modulation and coding rate to the most valuable services. Service pricing is beyond the scope of this paper, but it should be noted that charging 'by the minute' makes small-bandwidth services appear even more valuable.[2] Parameters of several services are provided in Table 3.

Service	Packet Size	Notes
full buffer	large	Academic – not a real traffic type
ftp	large	Common MTU 576 or 1500 bytes
http	medium to large	Common MTU 576 or 1500 bytes
WAP	small	mean 256 bytes [6]
streaming video	small	32kbps has mean packet size of 50 bytes [6]
TCP control for ftp and	small	Many 40 byte packets

[2] If a single WAP use (e.g., two 256 byte packets) is billed the same as a minute of ftp download (108kbytes at 14.4kbps), the revenue per byte for these two services can differ by a staggering 200x.

http		
video conferencing	small	32kbps circuit mode may be 80 bytes per 20ms
messaging	small	SMS sized text messages
VoIP	small	16kbps is 40 bytes per 20ms, sans overhead
interactive gaming	small	Quiz questions and answers similar to text messages, gambling
transaction-based apps	small	Finance/banking, m-commerce
location-specific services	small	Local info, ads, m-commerce
L3 signaling	small	Usually no more than a TCP ACK (40 bytes), often less
the next killer app?	?	?

Table 3. ***Services***

2.3. 1xEV-DV Integration into CDMA2000

Providing backwards compatibility with CDMA2000 is a key requirement for 1xEV-DV and a number of existing concepts from CDMA2000 is incorporated into 1xEV-DV. In fact, 1xEV-DV is revision C of the IS-2000 specification. The list of items reused from CDMA2000 includes:

1. The call signaling and Layer 3 procedures from IS-2000 are reused for 1xEV-DV. Supporting 1xEV-DV channels is met by modifying existing L3 messages. Also, the Layer 2 signaling protocol, Link Access Control (LAC) is reused.
2. The High Speed Packet Data Service Option (Service Option 33) is reused for 1xEV-DV. The same session states defined in the Service Option 33 specification are used for 1xEV-DV calls.
3. Minor updates have been made to the Radio Link Protocol (RLP) to account for modifications in the NAK timer procedures.
4. The existing CDMA2000 common channels (e.g., F-PCH, R-ACH) are also part of the 1xEV-DV air interface. Their specification and use has not changed from their IS-2000 specification.
5. The existing CDMA2000 dedicated channels (e.g., F/R-DCCH, F/R-FCH, F/R-SCH) are also part of the 1xEV-DV air interface. Their specification and use has not changed from their IS-2000 specification.
6. The reverse link specification in 1xEV-DV is identical to the IS-2000 reverse link specification.
7. Authentication of a user has not changed from IS-2000.

This integration is best demonstrated in **Figure 8. 1xEV-DV Layer 1 Interfaces (Network Perspective)** which shows how the 1xEV-DV channels are integrated into the existing CDMA2000 architecture. The F-PDCH Control Function, which sits as an intermediate layer between the Physical Layer and the MAC layer, contains the new functions described in the last section[3]. The new 1xEV-DV control channels transfer required control information between the F-PDCH Control Function and the Physical Layer. The only 1xEV-DV channels that communicate with the MAC Layer is the F-PDCH that provides the pipe for transporting a user's control and bearer data. Also, no new service interfaces have been added to the LAC, L3 and Data Layers.

This integration benefits the operator by providing a smooth migration path from their deployed CDMA infrastructure. This feature also minimizes impacts to existing infrastructure as the operator upgrades their network to 1xEV-DV. The subscriber also has access to all legacy features provided in CDMA networks. Finally, the subscriber is guaranteed of owning a mobile device that can support both 1X and 1xEV-DV air interfaces, providing a single terminal that can operate over the operator's entire network.

[3] Except for the modulation and coding feature that is allocated to the Physical Layer.

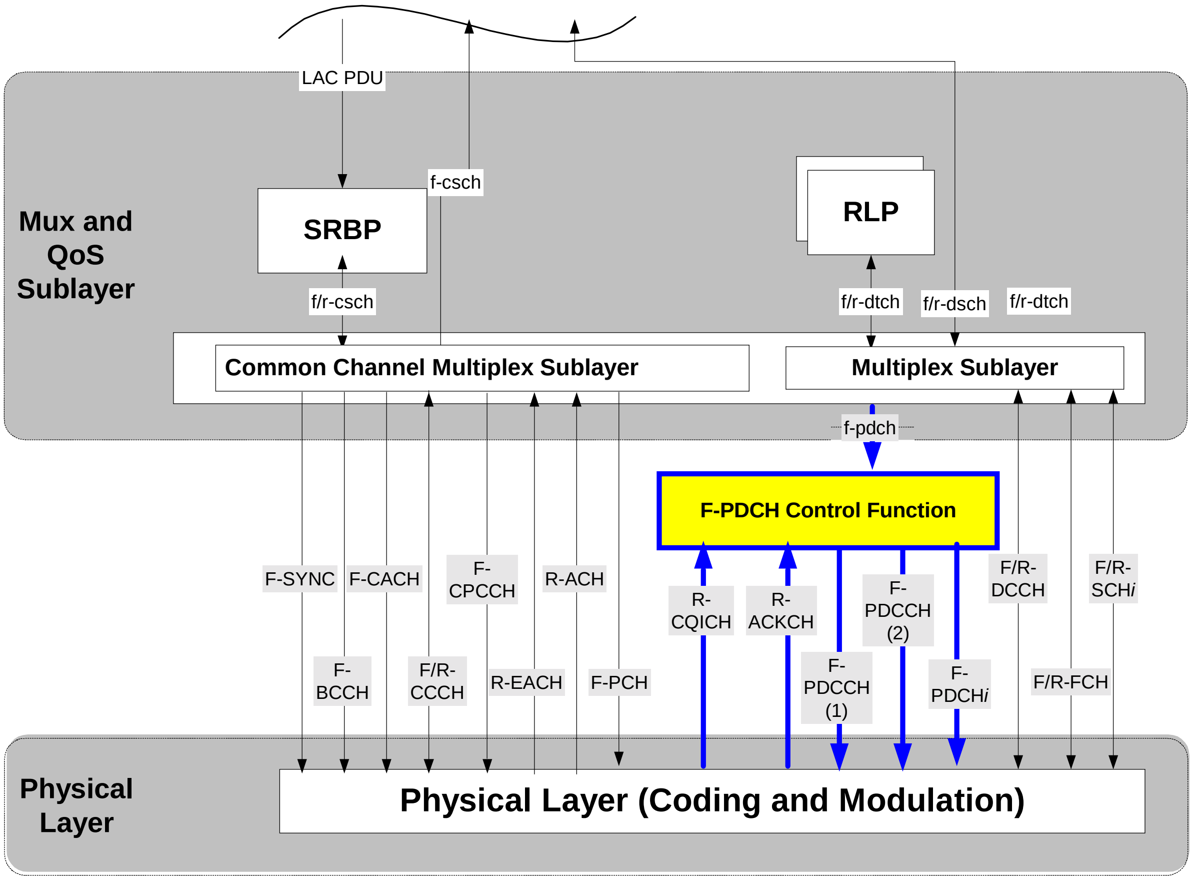


Figure 8. ***1xEV-DV Layer 1 Interfaces (Network Perspective)***

Another demonstration of how 1xEV-DV is a natural evolution of 1X is the traffic channel combinations supported in 1xEV-DV. **Table 4. 1xEV-DV Traffic Channel Combinations** demonstrates how the 1xEV-DV F-PDCH is integrated with the existing 1X traffic channels. The F-PDCH can be used in two modes. In the first mode, the F-PDCH is used in combination with a dedicated forward channel. In the second mode, the F-PDCH is the only forward traffic channel. In this mode, both signaling and bearer traffic are multiplexed in the F-PDCH. In both modes, the IS-2000 reverse link traffic channels are always used and their selection follows the IS-2000 procedures. All channels are assumed to coexist on the same frequency.

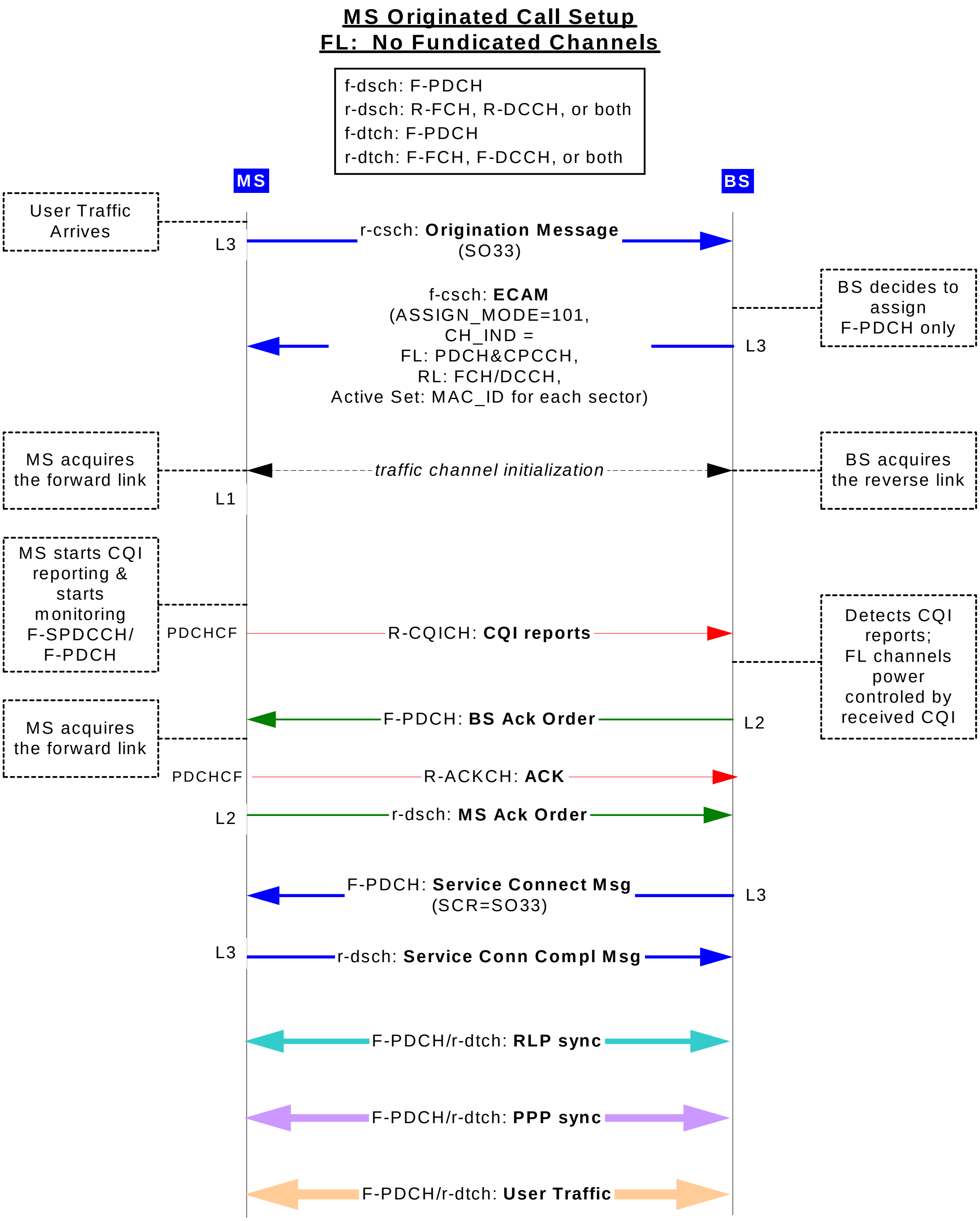
Traffic Channel Combinations	Typical Use
F-PDCH + F/R-FCH + F/R-DCCH	Mixed voice and data services
F-PDCH + F/R-FCH + R-DCCH	Mixed voice and data services
F-PDCH + F/R-DCCH	Data-only services
F-PDCH + F/R-FCH	Mixed voice and data services
F-PDCH + F-CPCCH + R-DCCH	Data-only services
F-PDCH + F-CPCCH + R-FCH	Data-only services

Table 4. ***1xEV-DV Traffic Channel Combinations***

These channel combinations provide the operator with the benefit of supporting both voice and data services in the forward and reverse links. If the subscriber wants to operate a data-only service, there are traffic channel combinations that allow the operator to optimize the data rate available to this subscriber (provide the subscriber one of the traffic channel combinations that provide only the F-PDCH in the forward link). If the subscriber wants to operate a mixed voice and data service, there are traffic channel combinations that allow the operator to provide the subscriber with a voice channel as well as a high-speed data channel (provide the subscriber one of the traffic channel combinations that provide a F-PDCH along with a F-FCH or F-DCCH in the forward link). This provides the operator with a very flexible method for using spectrum.

2.4. 1xEV-DV Call Flow

This section presents two example call flows for 1xEV-DV. The first call flow shows the sequence for establishing a 1xEV-DV call with no dedicated forward traffic channels. In this flow, IS-2000 Layer 3 messages are sent over the common channels for the initial stages of call setup and the F-PDCH is used for both signaling traffic and user traffic. Observe that the F-PDCH carries both the signaling traffic that would normally be sent over a dedicated traffic channel as well as the bearer traffic normally sent using either a dedicated channel or a supplemental channel. The second call flow shows the sequence for establishing a 1xEV-DV call with dedicated forward traffic channels. In this flow, IS-2000 Layer 3 messages are sent over the common channels for the initial stages of call setup while a dedicated channel is used for signaling and the F-PDCH is used for user traffic. Observe that a dedicated channel carries the signaling traffic while the bearer traffic is sent using a F-PDCH.



1
2 **Figure 9.** ***1xEV-DV Origination without a Dedicated Traffic Channel***

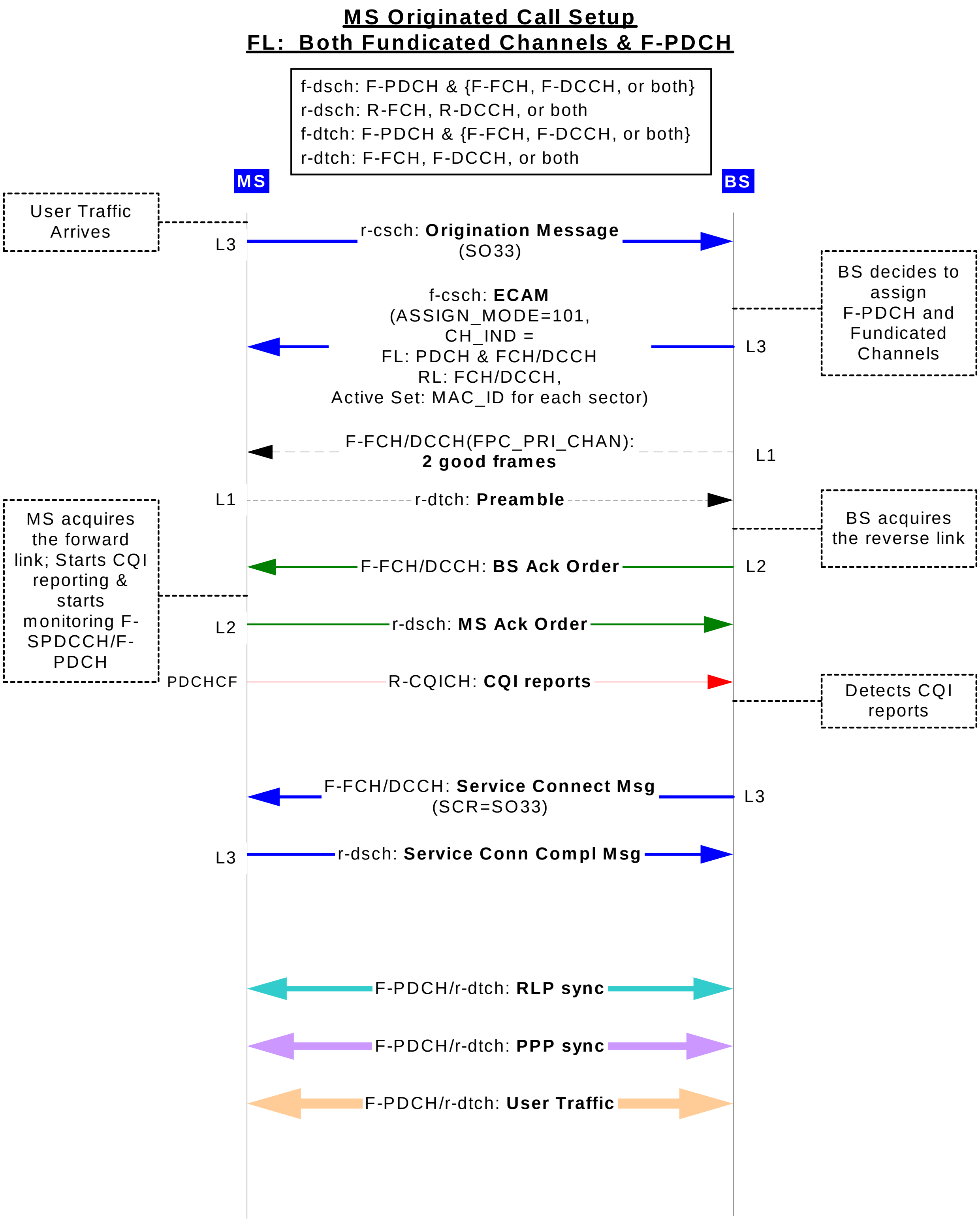


Figure 10. ***1xEV-DV Origination with a Dedicated Traffic Channel***

3. Conclusion

As a continuation of CDMA2000 1X (Release A/B) standards, 1xEV-DV will extend the evolution as CDMA2000 Release C, and later with further enhancements as Release D. While maintaining key functionalities of CDMA2000 1X, 1xEV-DV will provide additional data capabilities while preserving full backward compatibility with IS-95A/B and CDMA2000 1X. At peak data rate of 3.1 Mbps and average throughput of 1.0 Mbps, services requiring higher bandwidth and real-time capabilities can be supported in addition to the existing voice and data services.

1xEV-DV technologies will enable operators to fully leverage their investments in CDMA networks to maximize their return on investments. 1xEV-DV, as the natural extension of CDMA2000 1X, will enable operators to offer new data services while providing continuity for their existing services such as simultaneous voice and data. With the backward compatibility of 1xEV-DV with IS-95A/B and 1X, operators will be able to reuse network components deployed for 1X while providing additional data capabilities resulting in minimum CapEx required to offer new services. These benefits will ultimately lead to more competitive market positions for CDMA operators.

The availability of 1xEV-DV products will provide a smooth upgrade for operators to evolve to 1xEV-DV. It is expected that minimum hardware upgrades will be required for operators to provide 1xEV-DV capabilities.

4. References

[1] 3GPP2, C.S0002-C Physical Layer Standard for cdma2000 Spread Spectrum Systems, Release C, Version 1.0, May 28, 2002.

[2] 3GPP2 WG5 ULAHG, 1xEV-DV Upper Layer Technical Report, Version 1.0, January 10, 2002.

[3] 3GPP2, C30-20020204011R1_TSGA_EVDV_Intro, “Introduction to 1xEV-DV Air Interface”.

[4] 3GPP2, S.R0026, High Speed Data Enhancements for cdma2000 1X - Integrated Data and Voice”.

[5] 3GPP2 C.S0024, "cdma2000 High Rate Packet Data Air Interface Specification Version 3.0," December 5, 2001.

[6] “1xEV-DV Evaluation Methodology – Addendum (V6),” 3GPP2 WG5 Evaluation Ad Hoc, July 25, 2001.

[7] C50-20010820-011, "Results of L3NQS Simulation Study," August 20, 2001