

Time Division Duplex (TDD) vs Frequency Division Duplex (FDD) in Wireless Backhuls

The Goal of a Wireless Network

The convergence of voice, video and data services is the ultimate goal of many communication service providers. To achieve this goal, technologies associated with the traditional voice dominated network are replaced by newer technologies that accommodate the bandwidth demands of today's consumer. Access schemes, such as Frequency Division Multiple Access (FDMA) and Frequency Division Duplex (FDD), were regarded as innovative technologies when first applied to the requirements of the traditional voice network. Today, however, there are other technologies on the market that allow for the performance required to meet the high bandwidth demands and the dynamic nature of the current network that must deliver voice, video, Internet and data services efficiently.

FDD and TDD

Frequency Division Duplex (FDD) and Time Division Duplex (TDD) are the two most prevalent duplexing schemes used in fixed broadband wireless networks. FDD, which historically has been used in voice-only applications, supports two-way radio communication by using two distinct radio channels. Alternatively, TDD uses a single frequency to transmit signals in both the downstream and upstream directions.

In fixed wireless point-to-point systems that use FDD, one frequency channel is transmitted downstream from a radio A to radio B. A second frequency is used in the upstream direction and supports transmission from radio B to radio A. Because of the pairing of frequencies, simultaneous transmission in both directions is possible. To mitigate self-interference between upstream and downstream transmissions, a minimum amount of frequency separation must be maintained between the frequency pair.

In fixed wireless point-to-point systems that use TDD, a single frequency channel is used to transmit signals in both the downstream and upstream directions.

Data Symmetry

FDD systems utilize channel plans that are comprised of frequencies with equal bandwidth. Since each channel has a fixed bandwidth, the channel capacity of each frequency also is fixed and equal to that of all other channels in the frequency band. This makes FDD ideal for symmetrical communication applications in which the same or similar information flows in both directions, such as voice communications.

TDD operates by toggling transmission directions over a time interval. This toggling takes place very rapidly and is imperceptible to the user. Thus, TDD can support voice and other symmetrical communication services as well as asymmetric data services. TDD also can handle a dynamic mix of both traffic types. The relative capacity of the downstream and upstream links can be altered in favor of one direction over the other. This is accomplished by giving a greater time allocation through time slots to downstream transmission intervals than upstream. This asymmetry is useful for communication processes characterized by unbalanced information flow. An obvious application for this technique is Internet access in which a user enters a short message upstream and receives large information payloads downstream.

FDD can be used for asymmetric traffic. However, in order to be spectrally efficient, the downstream and upstream channel bandwidths must be matched precisely to the asymmetry. Since Internet traffic is bursty by nature and the asymmetry is always changing, the channel bandwidth cannot be precisely set in FDD. In this respect, TDD is more efficient. Furthermore, channel bandwidths typically are set by the FCC or limited by the functionality of available equipment. As a consequence, users of FDD systems do not have the option to vary channel bandwidths dynamically in the upstream and downstream directions.

Spectrum Efficiency

Frequency spectrum is an increasingly scarce commodity. This scarcity drives the need to optimize the use of available bandwidth. FDD systems operate on the principle of paired frequencies. A channel plan is devised that is comprised of downstream and upstream channels, typically defined by the FCC, ITU, or other governing body.

FDD channel plans maintain a guardband between the downstream and upstream channels. The guardband is required to avoid self-interference and, since it is unused, essentially is wasted spectrum.

In contrast, TDD systems require a guard time (instead of a guardband) between transmit and receive streams. The TX/RX Transition Gap (TTG) is a gap between downstream transmission and the upstream transmission. This gap allows time for the base station to switch from transmit mode to receive mode and subscribers to switch from receive mode to transmit mode. During this gap, the base station and subscriber are not transmitting modulated data but are simply allowing the base station transmitter carrier to ramp down, the TX /RX antenna switch to actuate, and the base station receiver section to activate.

Conclusions

The above discussion has highlighted the differences and some significant advantages of TDD over FDD. These advantages can be summarized as follows:

- FDD is an older scheme that was best suited for applications, such as voice, that generate symmetric traffic, while TDD is best suited for bursty, asymmetric traffic, such as Internet or other datacentric services.
- In TDD, both the transmitter and receiver operate on the same frequency but at different times. Therefore, TDD systems reuse the filters, mixers, frequency sources and synthesizers, thereby eliminating the complexity and costs associated with isolating the transmit antenna and the receive antenna. An FDD system uses a duplexer and/or two antennas that require spatial separation and, therefore, cannot reuse the resources. The result is more costly hardware.
- TDD utilizes the spectrum more efficiently than FDD. FDD cannot be used in environments where the service provider does not have enough bandwidth to provide the required guardband between transmit and receive channels.
- TDD is more flexible than FDD in meeting the need to dynamically reconfigure the allocated upstream and downstream bandwidth in response to customer needs.
- TDD allows interference mitigation via proper frequency planning. TDD requires only one interference-free channel compared with FDD, which requires two interference-free channels.
- In summary, TDD is a more desirable duplexing technology that allows system operators to receive the most from their investment in spectrum and telecom equipment, while meeting the needs of each individual customer.