EEE4121F-A
Mobile and Wireless Networks

Multiple Access and Duplex
Part 2

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Radio Access in 3G

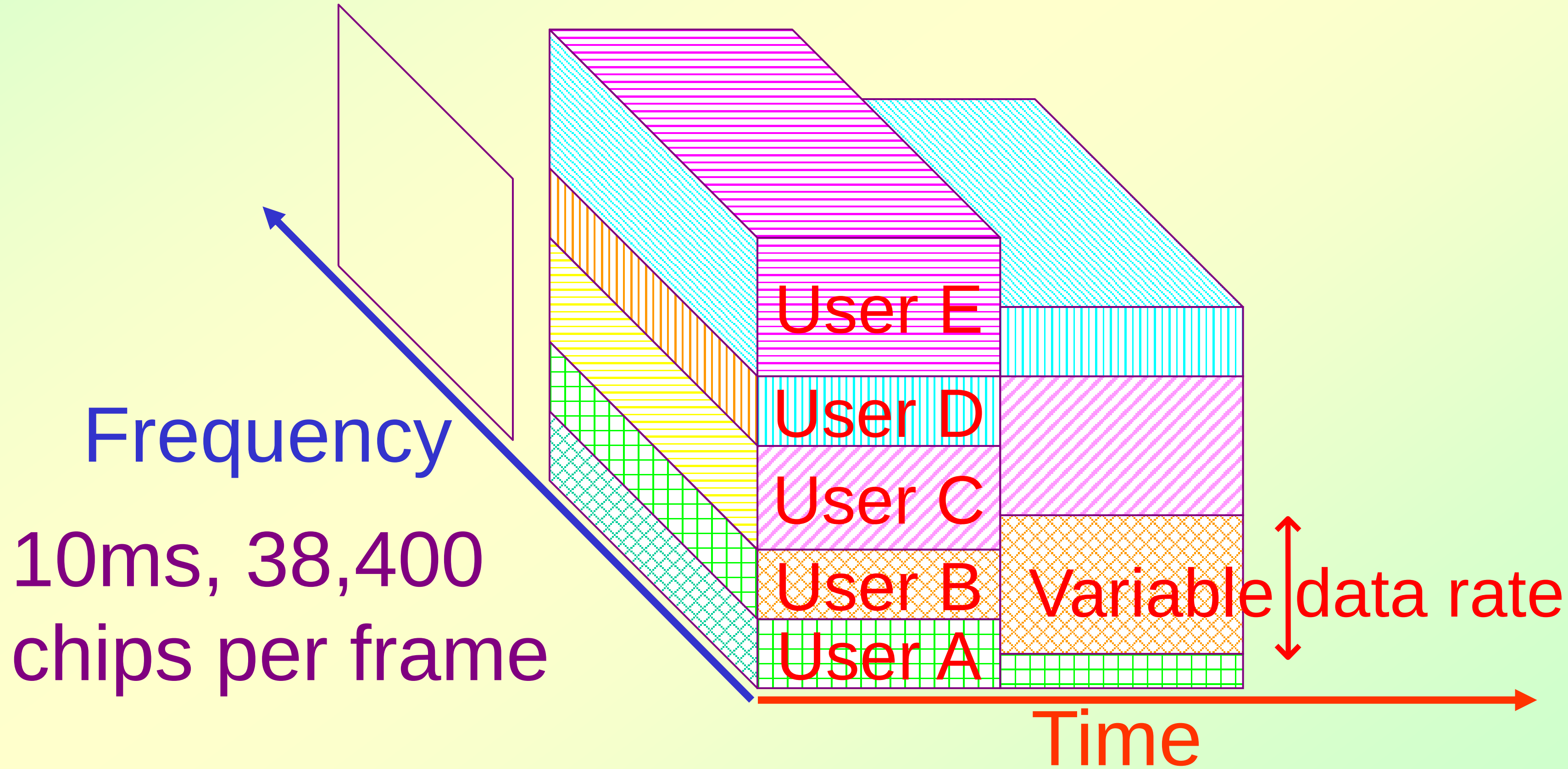
- DS-CDMA: Direct Sequence CDMA
- also called DS/SS Direct Sequence Spread Spectrum
- MC-CDMA: Multi-carrier CDMA
- TD-SCDMA: Time Division-Synchronous CDMA

Radio Access in 3G

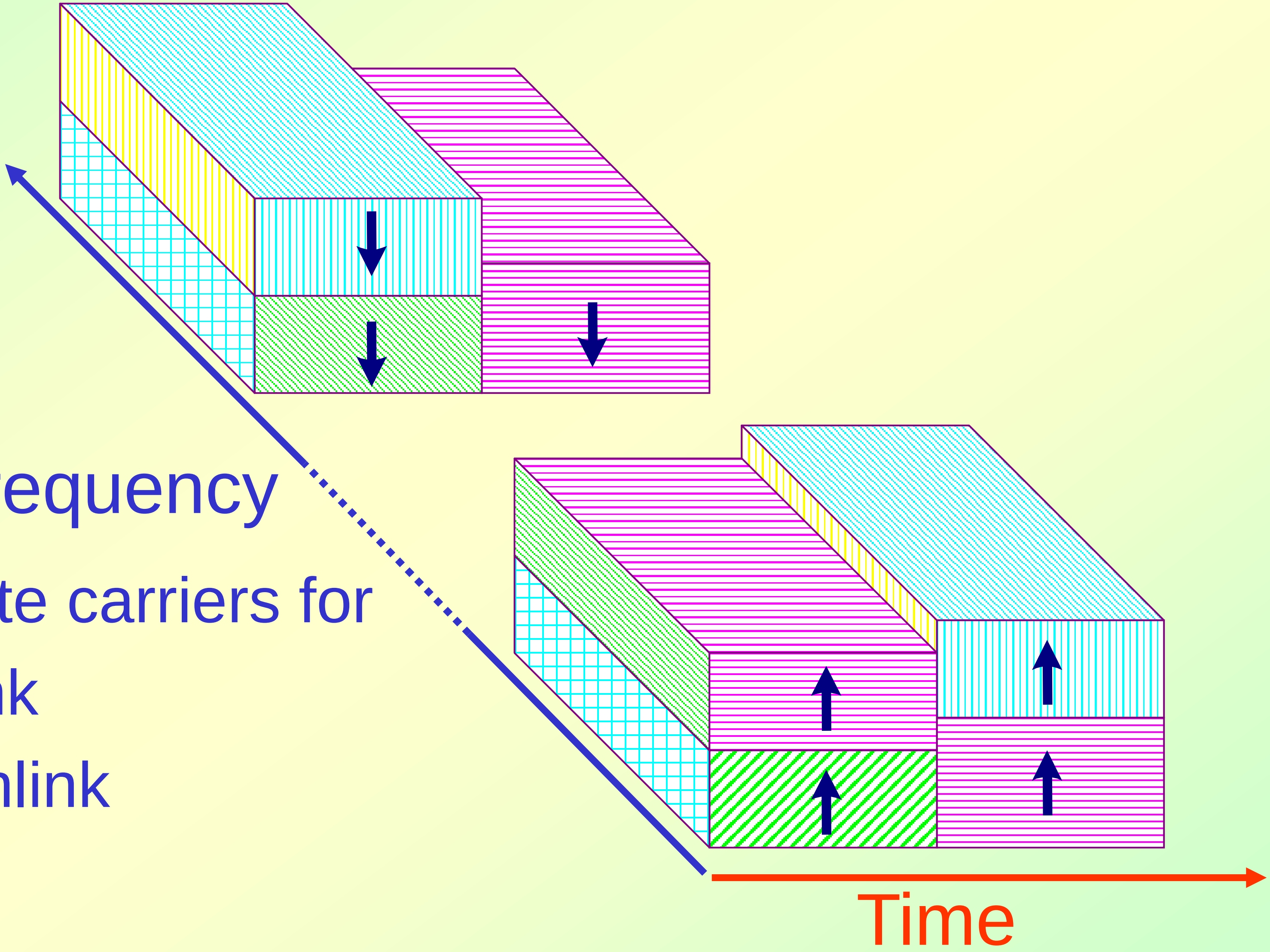
Technology	3G standard	
TDMA	EDGE	200kHz; 1.6MHz
DS-CDMA FDD	UTRA FDD WCDMA	5MHz; 3.84Mcps Radio Access
DS-CDMA TDD	UTRA TDD	5MHz; 3.84Mcps; or 1.6MHz; 1.28Mcps
MC-CDMA	Cdma2000	3 x 1.25Mz; 3.6864Mcps chip rate

Wideband CDMA

- WCDMA allocates 10 ms (38,400 chips) frames to users. The data rate for a user may change from frame to frame.



Wideband CDMA
UTRA/FDD



- Separate carriers for
  - Uplink
  - downlink

Wideband CDMA UTRA/FDD

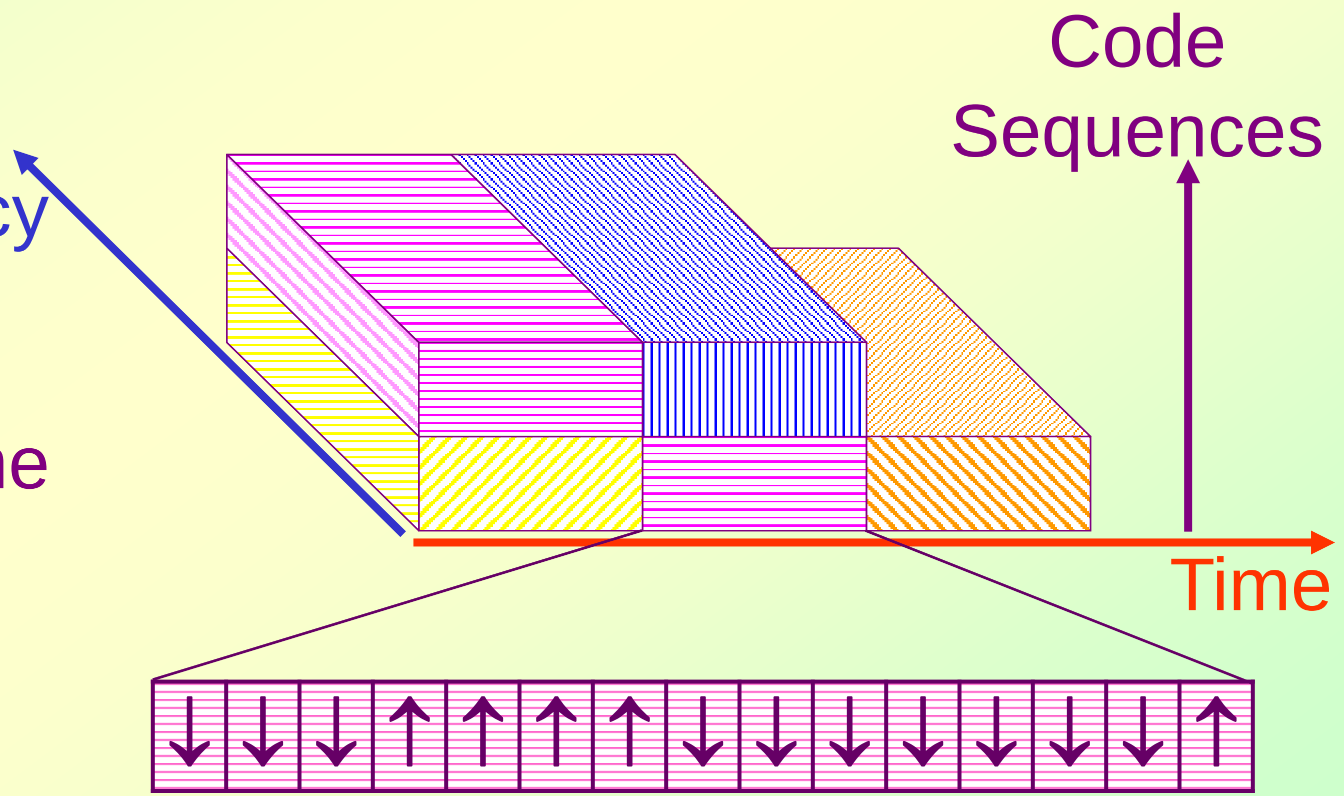
Spreading Factor (# of chips per symbol)	Symbol Rate	Max. user data rate with 1/2 coding
512 (downlink only)	750 symbols/s	375 bps
256	15k symbols/s	7.5 kbps
128	30k symbols/s	15 kbps
64	60k symbols/s	30 kbps
32	120k symbols/s	60 kbps
•••	•••	•••

Wideband CDMA
UTRA/FDD

Spreading Factor	Symbol Rate	Max. user data rate with 1/2 coding
•••	•••	•••
16	240k symbols/s	120 kbps
8	480k symbols/s	240 kbps
4	960k symbols/s	480 kbps
4 with 6 codes	5.76M symbols/s	$\geq$ 2 Mbps

Wideband CDMA UTRA/TDD

- Each 10 ms frame is divided into 15 timeslots
- Each timeslot (2,560 chips) in a frame may be allocated to uplink or downlink transmission as needed

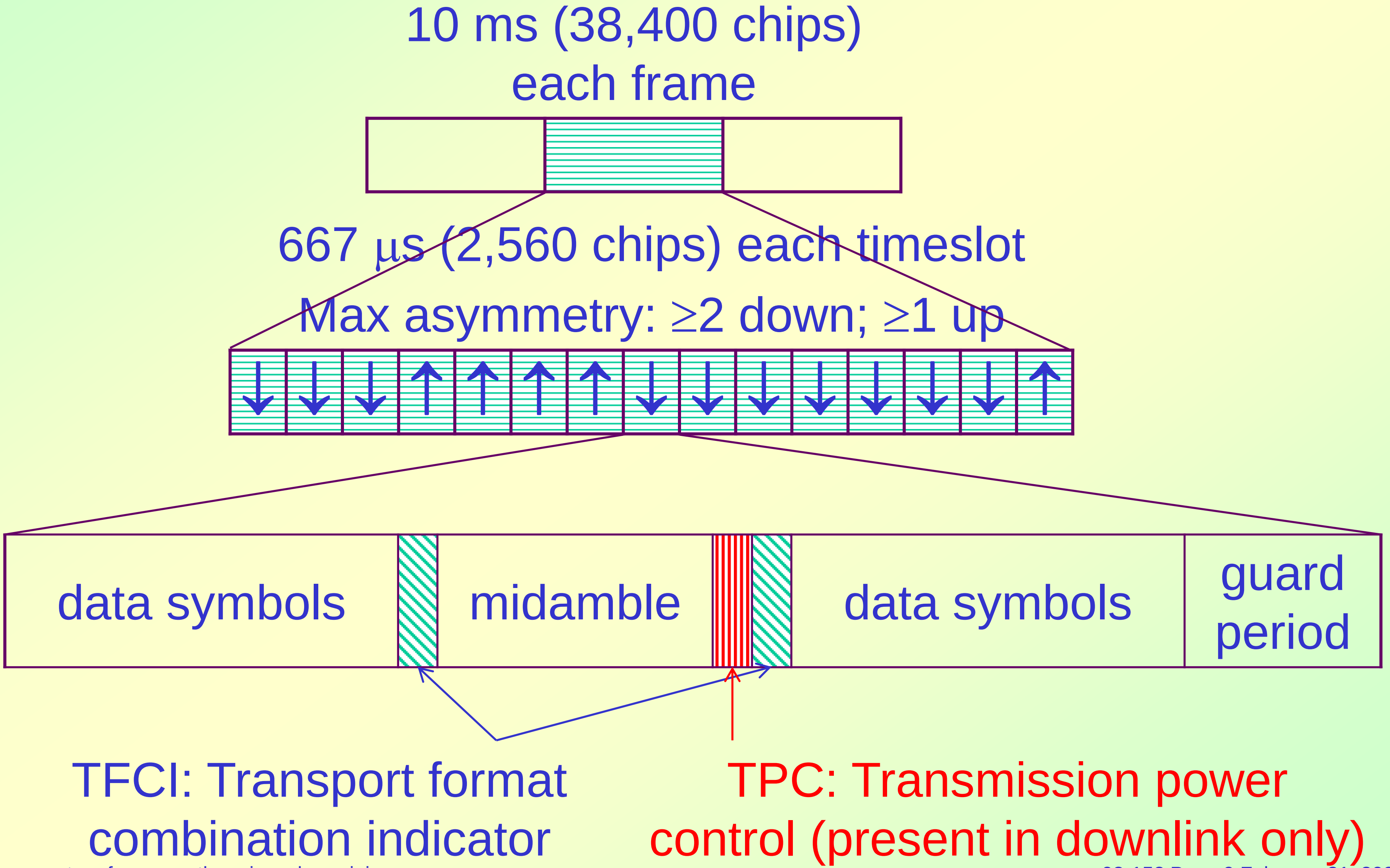


10ms, 38,400 chips per frame

667μs, 2,560 chips per slot

At the counter of success there is no bargaining.
A price must be paid in advance, and in full.

Wideband CDMA
UTRA/TDD



Narrowband CDMA UTRA/TDD

- Each 10 ms frame (12,800 chips) is divided into two 5 ms sub-frames, each with 10 timeslots
- The spreading factors are from 16 to 1

UTRA
FDD and TDD

- FDD
- Two symmetric channels, for uplink and downlink, are needed. The spectrum for uplink and downlink are separated to avoid interference

- TDD
- Bands are unpaired and so are more flexible. It is easier to obtain frequency spectrum

UTRA
FDD and TDD

- FDD
- Operation is fully and continuously duplex, i.e., Mobile and base station may transmit and receive at the same time

- TDD

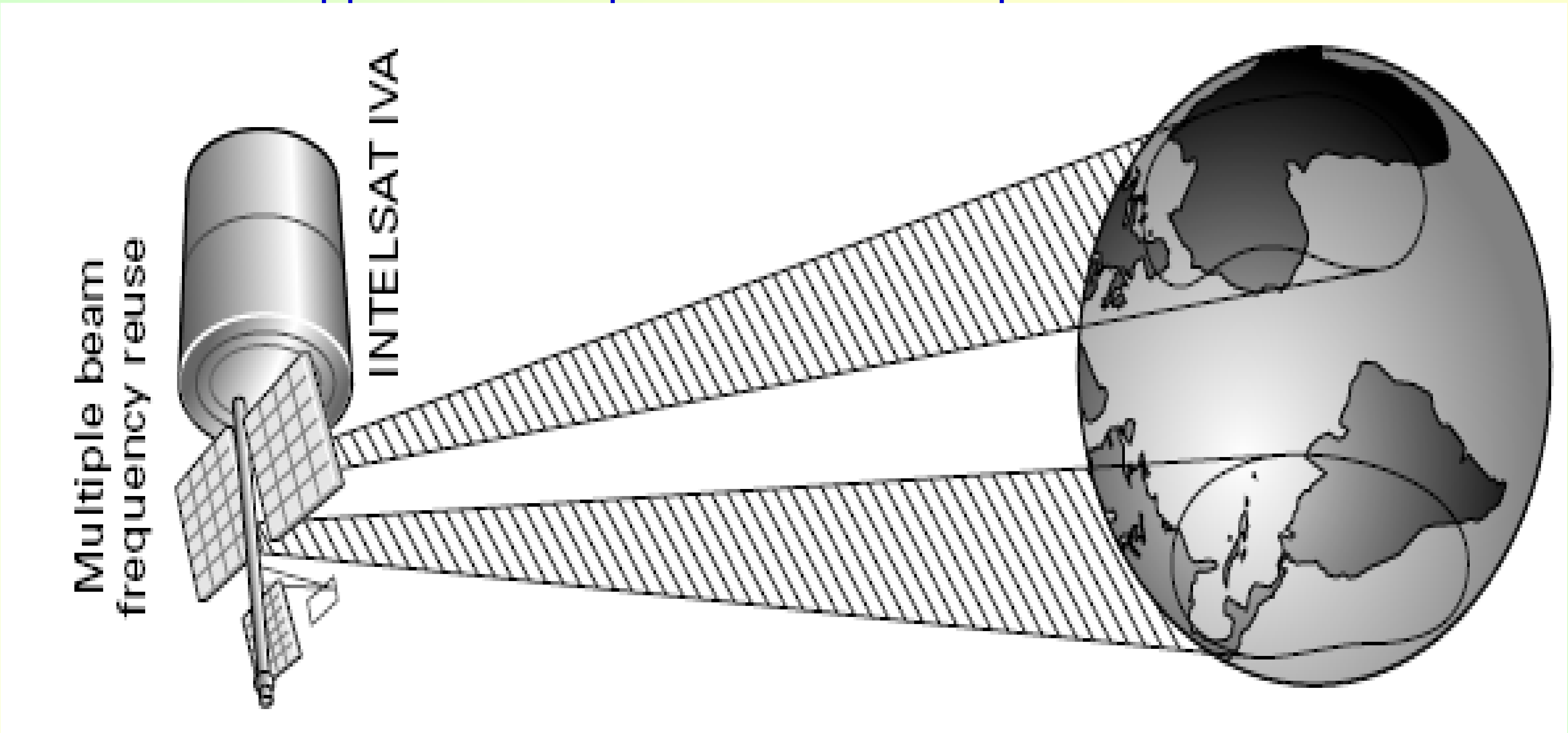
UTRA
FDD and TDD

- FDD
- Utilization of carrier is poor when the uplink and downlink traffic are not symmetrical

- TDD
- Flexible allocation of timeslots to uplink or downlink enables efficient use of carrier especially when the uplink and downlink traffic are not symmetrical

(a) Space-Division and Polarization-Division Multiple access

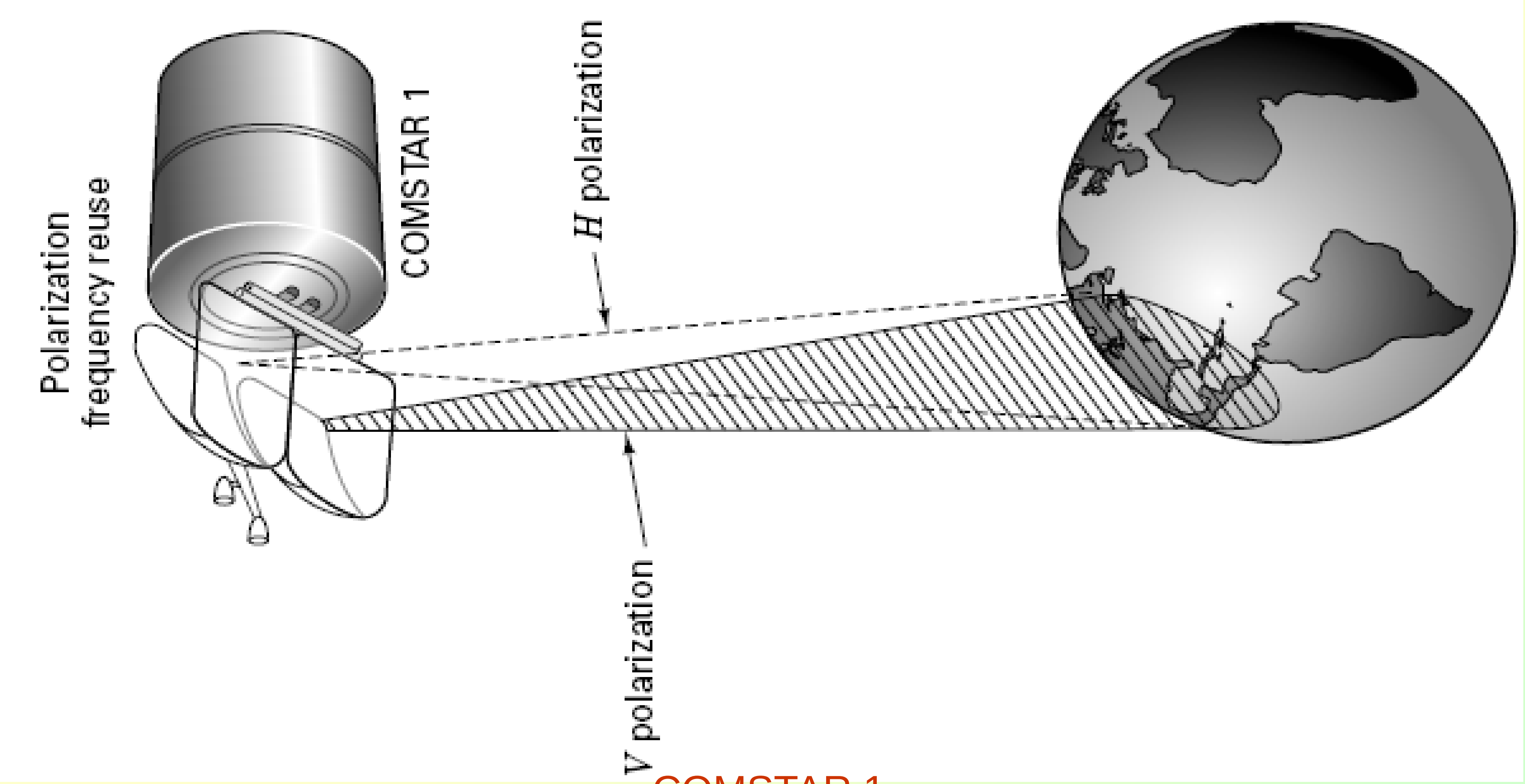
Application of space-division multiple access SDMA



INTELSAT IVA (Multiple-beam frequency reuse)

(b) Space-Division and Polarization-Division Multiple access

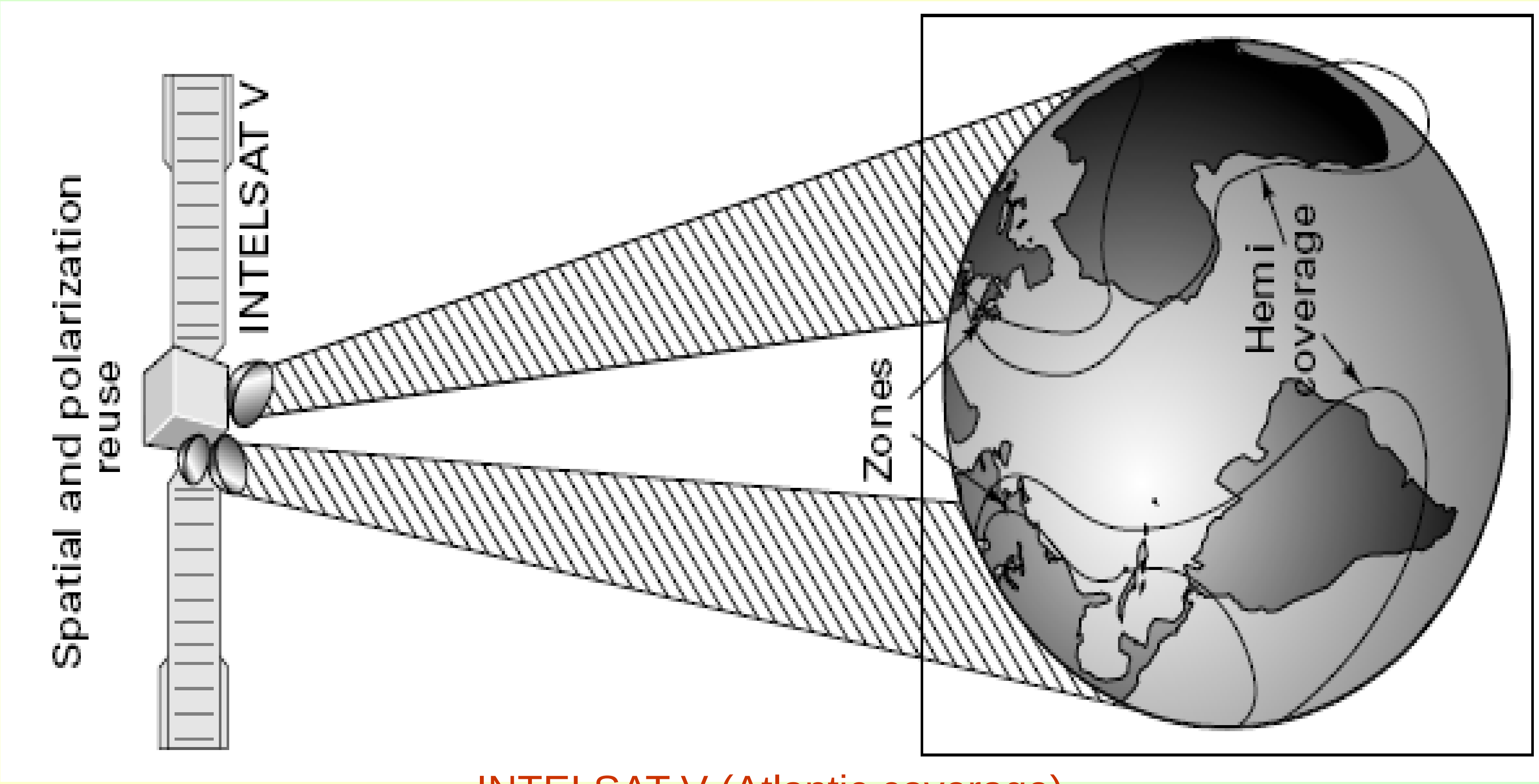
Application of polarization-division multiple access PDMA



COMSTAR 1

(C) Space-Division and Polarization-Division Multiple access

Application of the simultaneously use of SDMA & PDMA

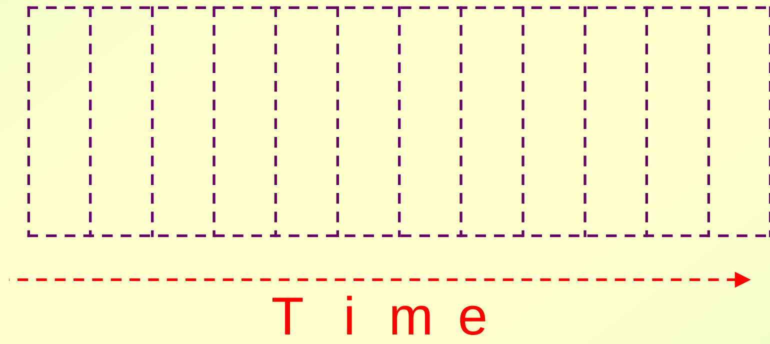


INTELSAT V (Atlantic coverage)

OFDM

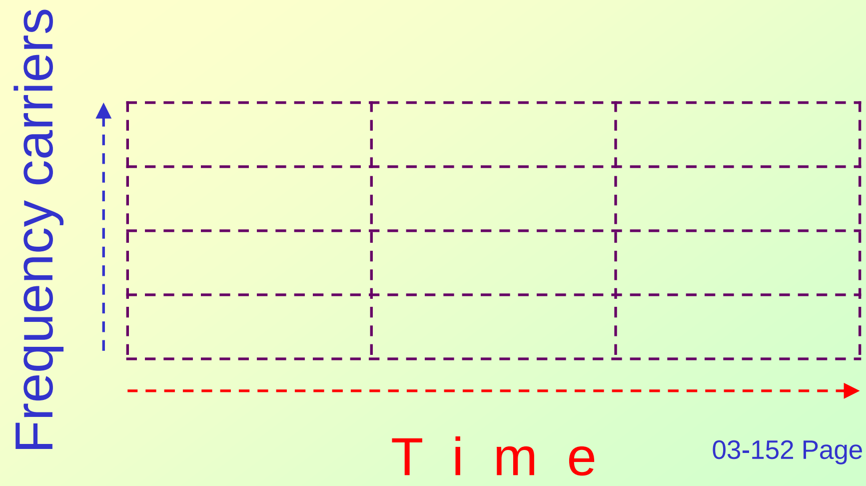
- Sending 12 symbols using single carrier

Split data stream into parallel sub-streams Modulate each sub-stream with a separate orthogonal carrier

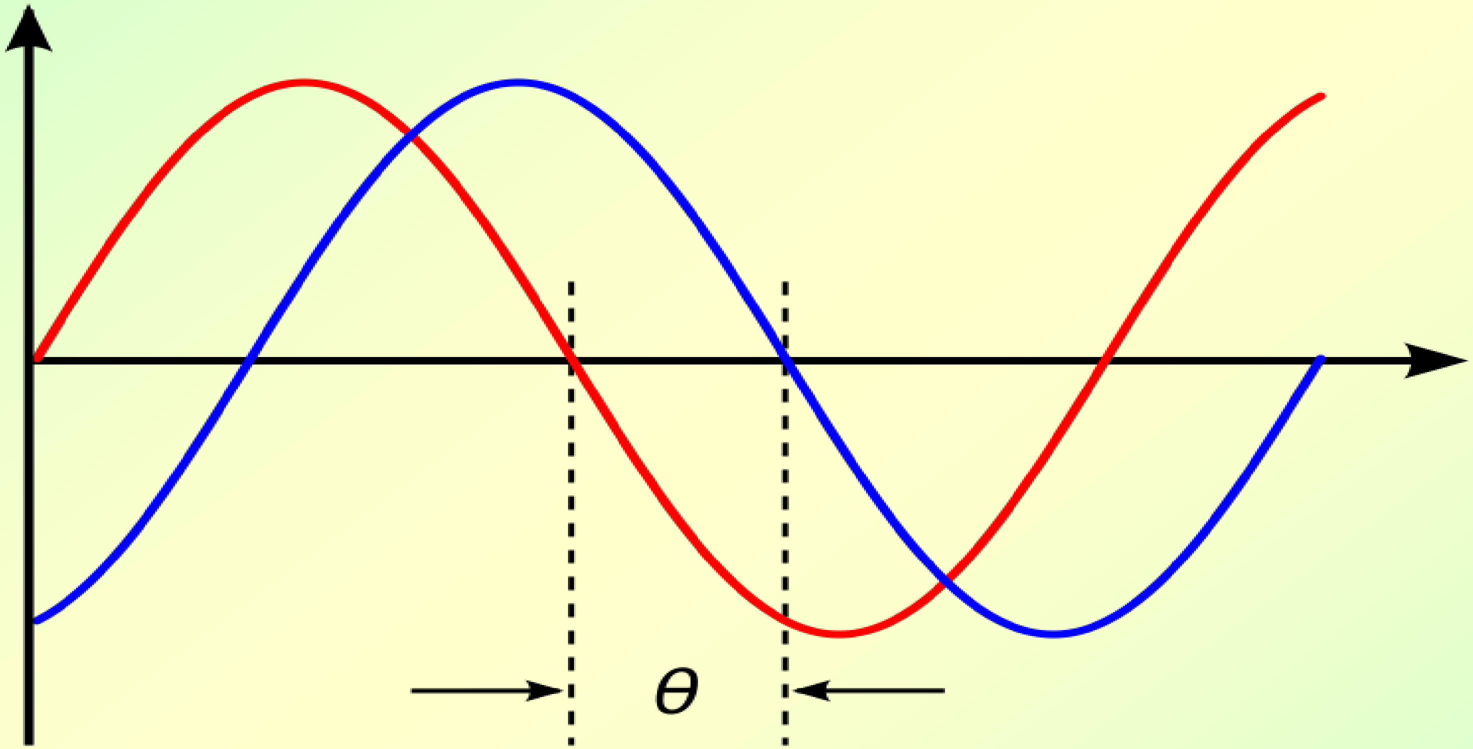


- Sending 12 symbols using OFDM

The sub-carriers are at lower data rate and therefore have longer symbol duration → more robust against Intersymbol Interference (ISI)



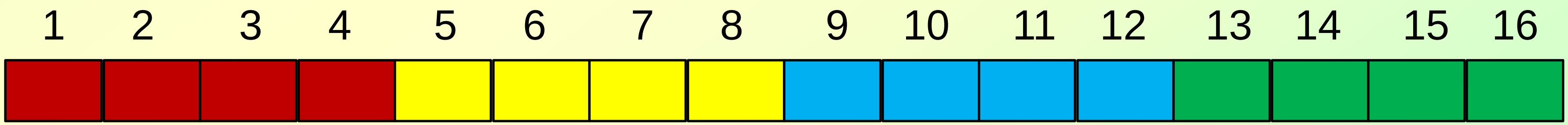
OFDM



Multipath interference is a phenomenon in the physics of wave whereby a wave from a source travels to a detector via two or more paths and, under the right condition, the two (or more) components of the wave interference

OFDMA

- Assume that a base station communicates with M users by exploiting N available subcarriers
- The available subcarriers (N) are evenly divided into R subchannels
- Each subchannel (P) consist of N/R subcarriers
- Assume that different subchannels are assigned to distinct users, even though in practice more subchannels may be allocated to the same user depending on its requested data rate
- Maximum number of users that the system can simultaneously support is limited to R, in the ensuing discussion we assume $M \leq R$



OFDMA

- The following diagram shows examples of subcarrier allocation schemes
- In the subband carrier assignment scheme (CAS) of Fig. X(a), each subchannel is composed by a group of P adjacent subcarriers.
- The main drawback of this approach is that it does not exploit the frequency diversity offered by the multipath channel since a deep fade might hit a substantial number of subcarriers of a given user.
- A viable solution to this problem is obtained by adopting the interleaved CAS shown in Fig. X(b), where the subcarriers of each user are uniformly spaced over the signal bandwidth at a distance R from each other.

OFDMA

- Although this method can fully exploit the channel frequency diversity, the current trend in OFDMA is to use a more flexible allocation strategy where users can select the best subcarriers [i.e., those with the highest signal-to-noise ratios (SNRs)] that are currently available.
- This scheme is called generalized CAS and its basic concept is shown in Fig. X(c).
- There is no rigid association between subcarriers and users, therefore the generalized CAS allows dynamic resource allocation and provides more flexibility than subband or interleaved CAS.

OFDMA

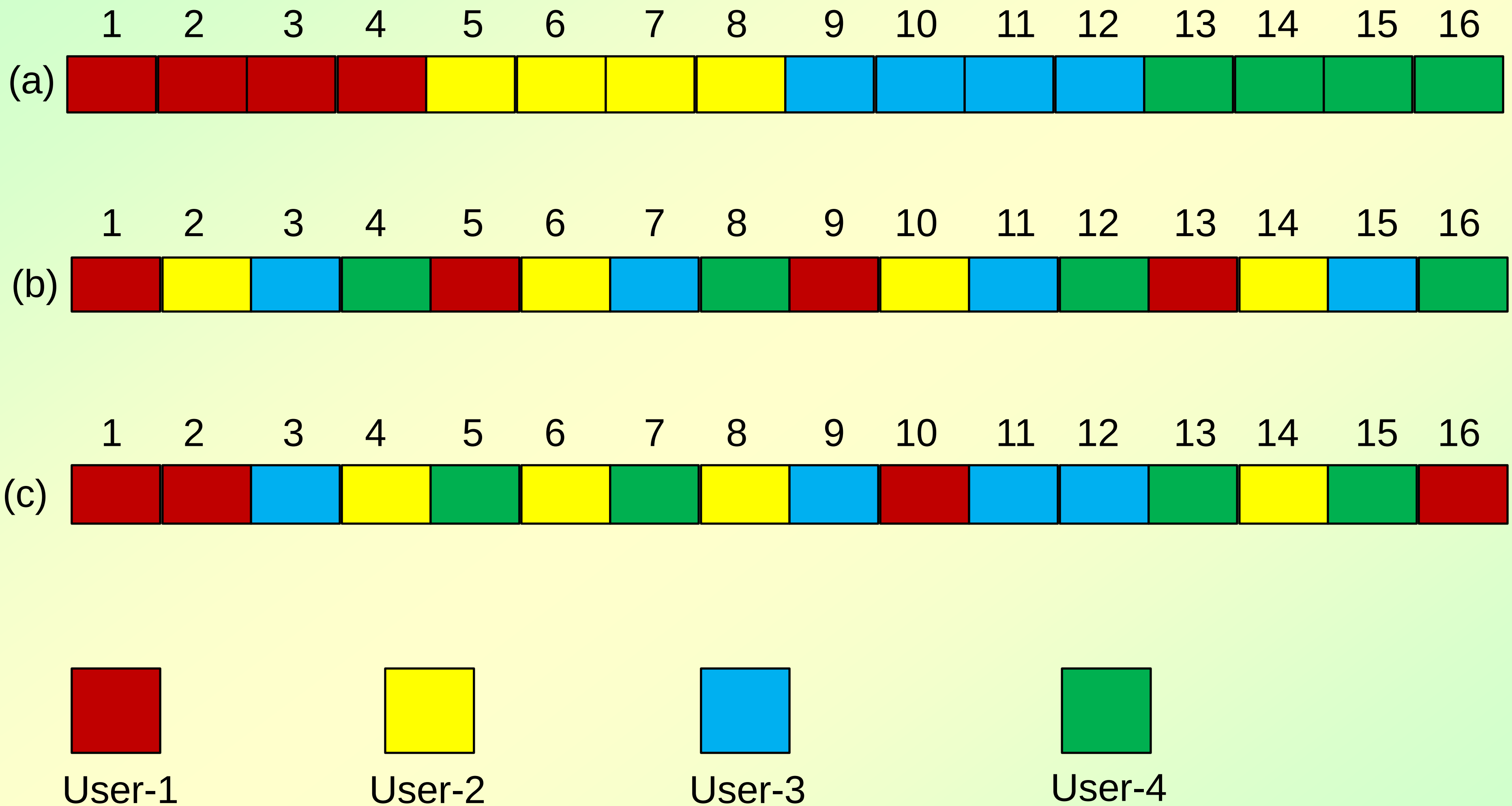


Fig x. Examples of subcarrier allocation schemes

OFDMA

- Divide carriers into N_G groups
- each with N_E sub-carriers

- In OFDM: 1 channel at a time, user transmits at all frequency carriers

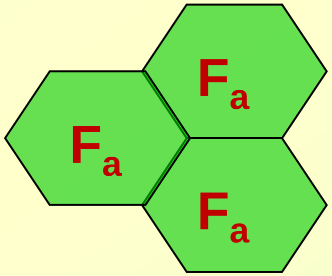
- Sub-channelization:
- OFDMA divide channel into N_E sub-channels, such that each sub-channel has one sub-carrier from each group

OFDMA (Used in 4G Network)

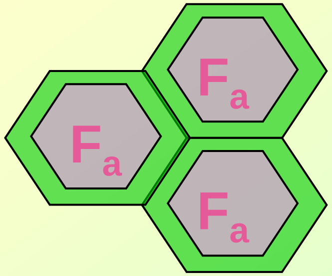
- Sub-channelization enables more efficient use of resources by managing bandwidth and power to transmit.
- E.g., may allocate less power for users with good channel conditions and vice versa
  - Devices may have limited power
- E.g., may allocate more power for sub-channels assigned to indoor users
- With OFDMA, a user is transmitting at its assigned sub-carriers only. It may concentrate the transmitted power at those sub-carriers.

Advantages of OFDMA over CDMA

- OFDM can combat multipath interference with more robustness and less complexity
- OFDMA can achieve a higher MIMO spectral efficiency due to providing flatter frequency channels than a CDMA RAKE receiver can
- No Cell size breathing as more users connect



CDMA cells before loading



CDMA cell after loading

None Orthogonal Multiple Access (NOMA)

- Non-orthogonal multiple access (NOMA) has been recently recognized as a promising multiple access technique to significantly improve the spectral efficiency of mobile communication networks.
- In 1G, 2G, and 3G, frequency division multiple access (FDMA), time division multiple access and code division multiple access were introduced, respectively.
- In Long-Term Evolution (LTE) and LTE-Advanced, orthogonal frequency division multiple access (OFDMA) and single-carrier (SC)-FDMA are adopted as an orthogonal multiple access(OMA) approach.
- Such an orthogonal design has the benefit that there is no mutual interference among users, and therefore good system-level performance can be achieved even with simplified receivers.
- However, none of these techniques can meet the high demands of future radio access systems such as 5G.

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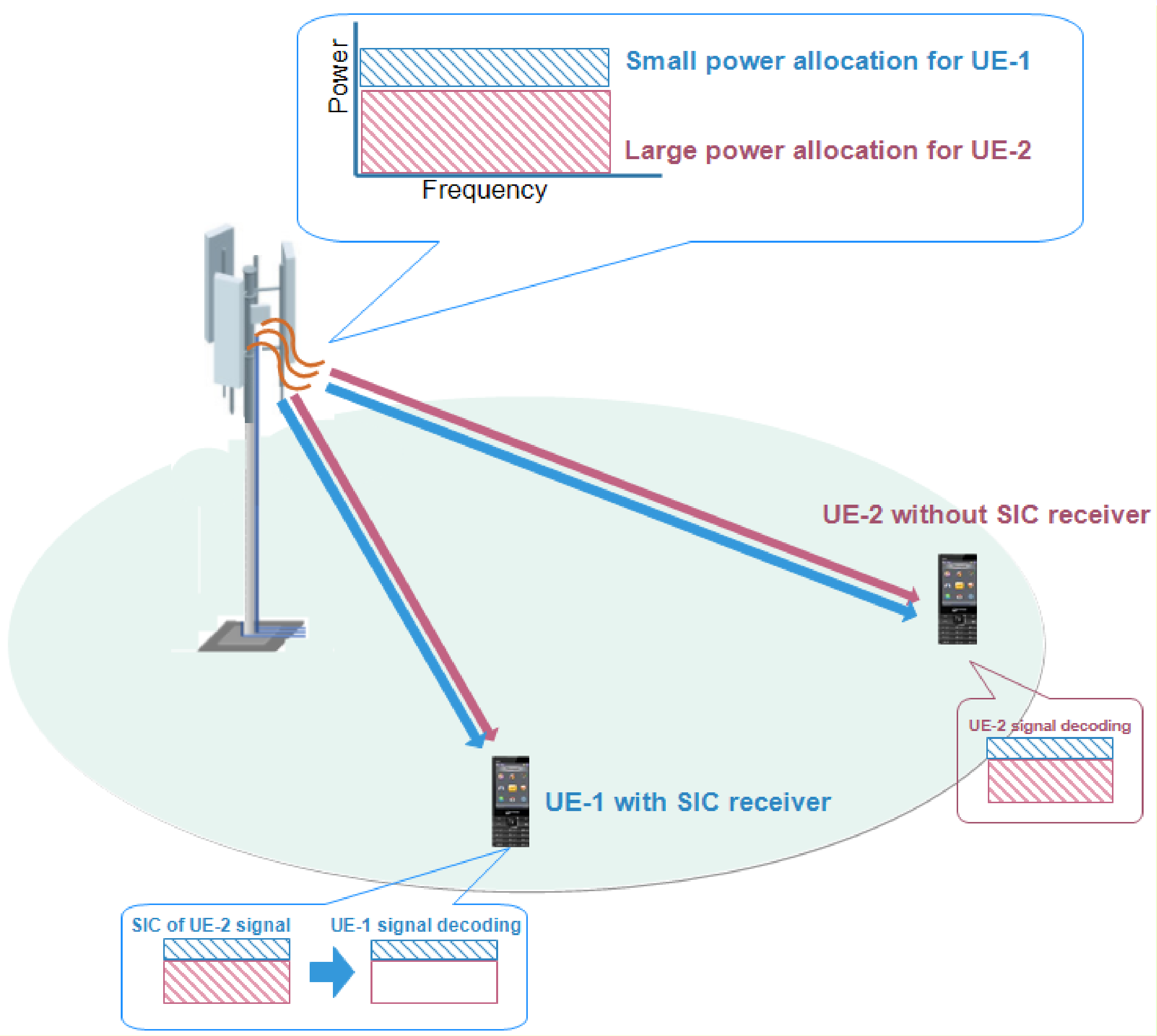
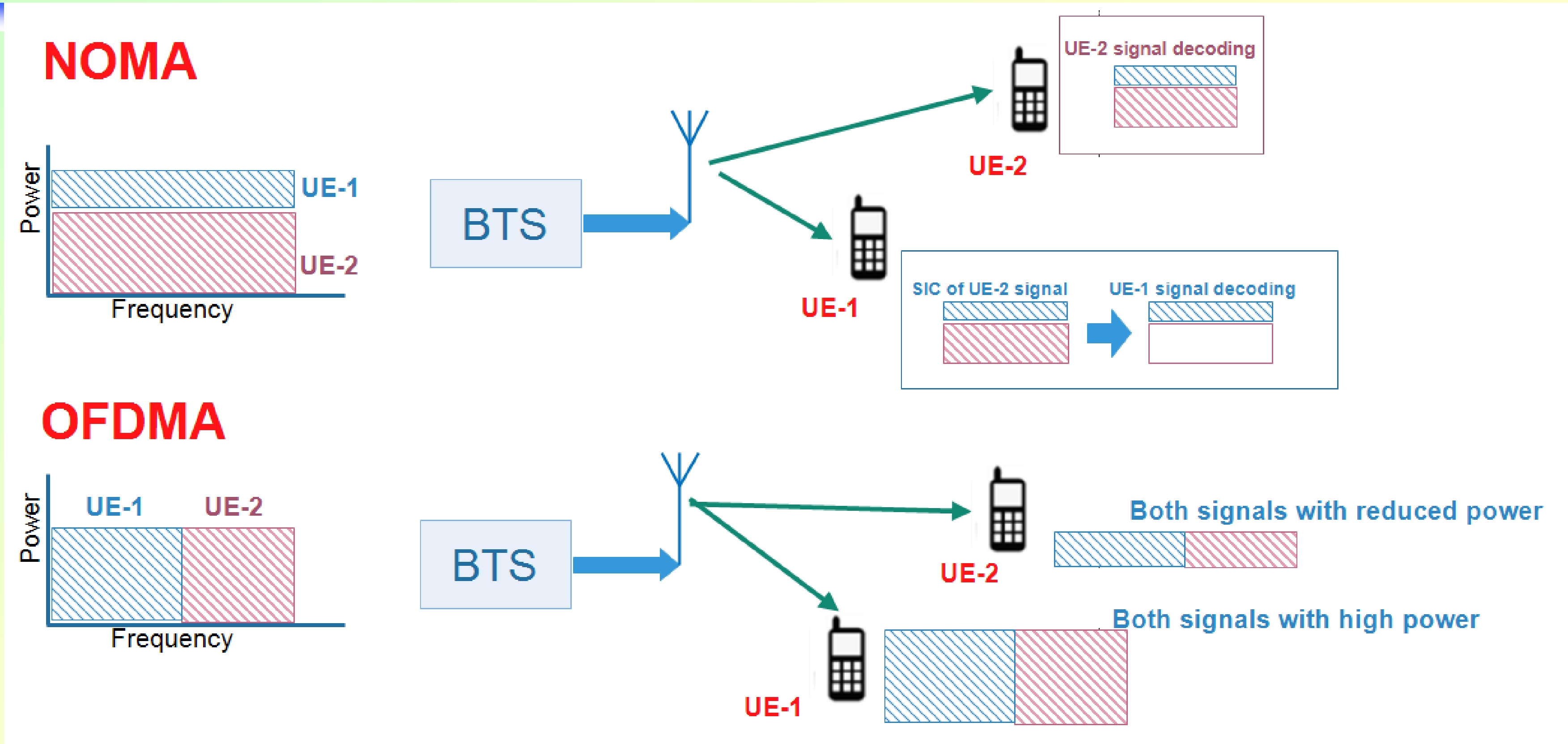


In downlink NOMA, the transmit signal from the BS and the received signal at both UE receivers is composed of a superposition of the transmit signals of both UEs.

Thus multi-user signal separation needs to be implemented at the UE side so that each UE can retrieve its signal and decode its own data. This can be achieved by non-linear receivers such as maximum likelihood detection or SIC (Successive Interference Cancellation).

Comparison of OFDMA and NOMA



- In OFDMA, different UE signals are transmitter at different frequency resources, but in case of NOMA, different UE signals are transmitted at same frequency but at different power levels depending upon the position of UE in the cell.

Comparison of OFDMA and NOMA

- The performance gain of NOMA compared to that of OFDMA increases when the difference in channel gain the path loss between UEs is large.

- According to this simple two-UE case, NOMA provides a higher sum rate than OFDMA. In fact, the cell-center UE gains in terms of rate since this UE is bandwidth-limited and thus benefits more from being able to use double bandwidth, even if this comes at the price of much lower transmit power.

- Meanwhile, the cell-edge UE also gains in terms of rate since it is power-limited; its transmit power is only slightly reduced under NOMA but its transmit bandwidth can be doubled.

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The greatest oak was once a little nut that held its ground.

Never quit!