

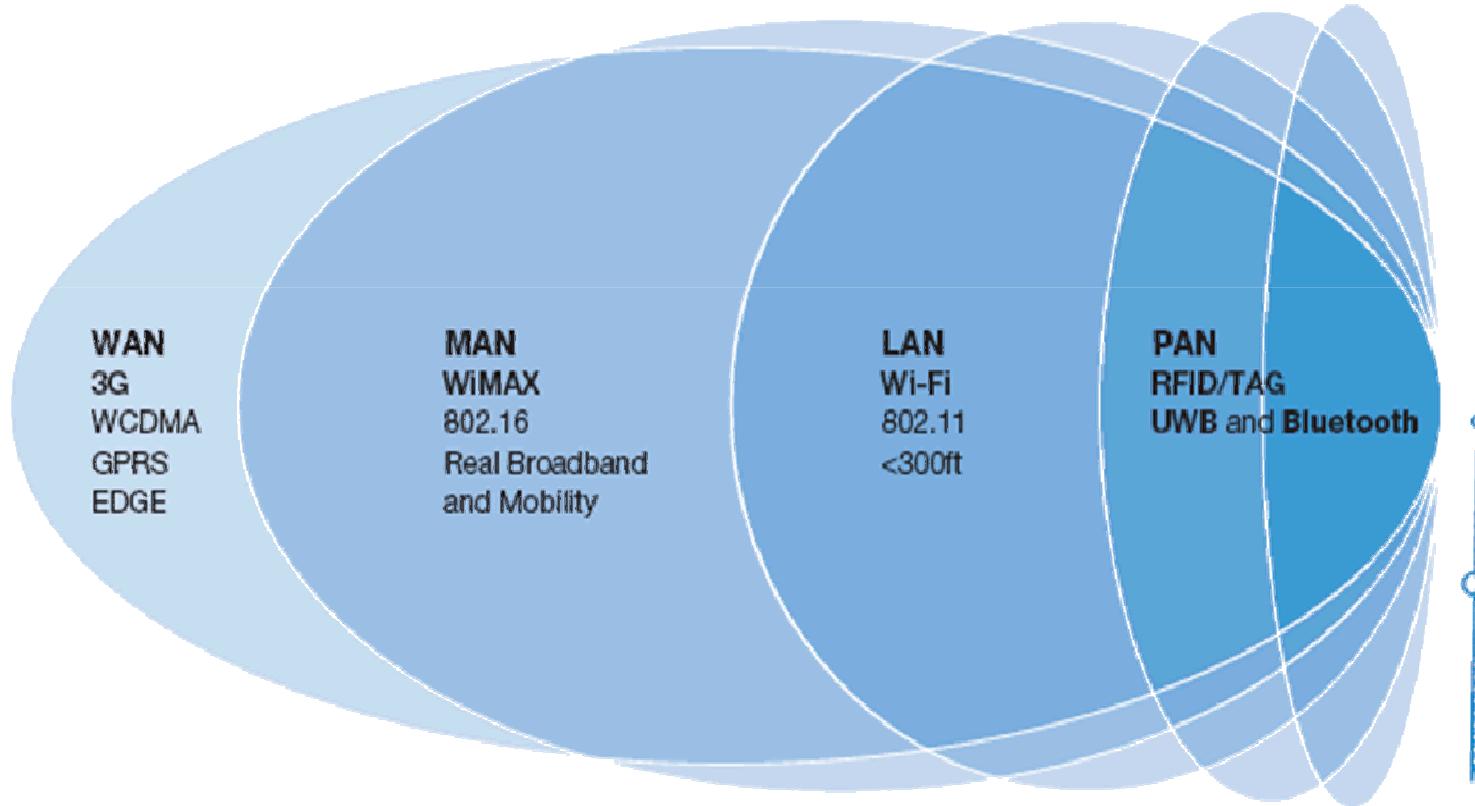
Aula anterior

- MACs de alto desempenho
 - SONET: núcleo de provedor
 - Fiber Channel: Storage Nets
 - Myrinet & Infiniband: cluster interconnection

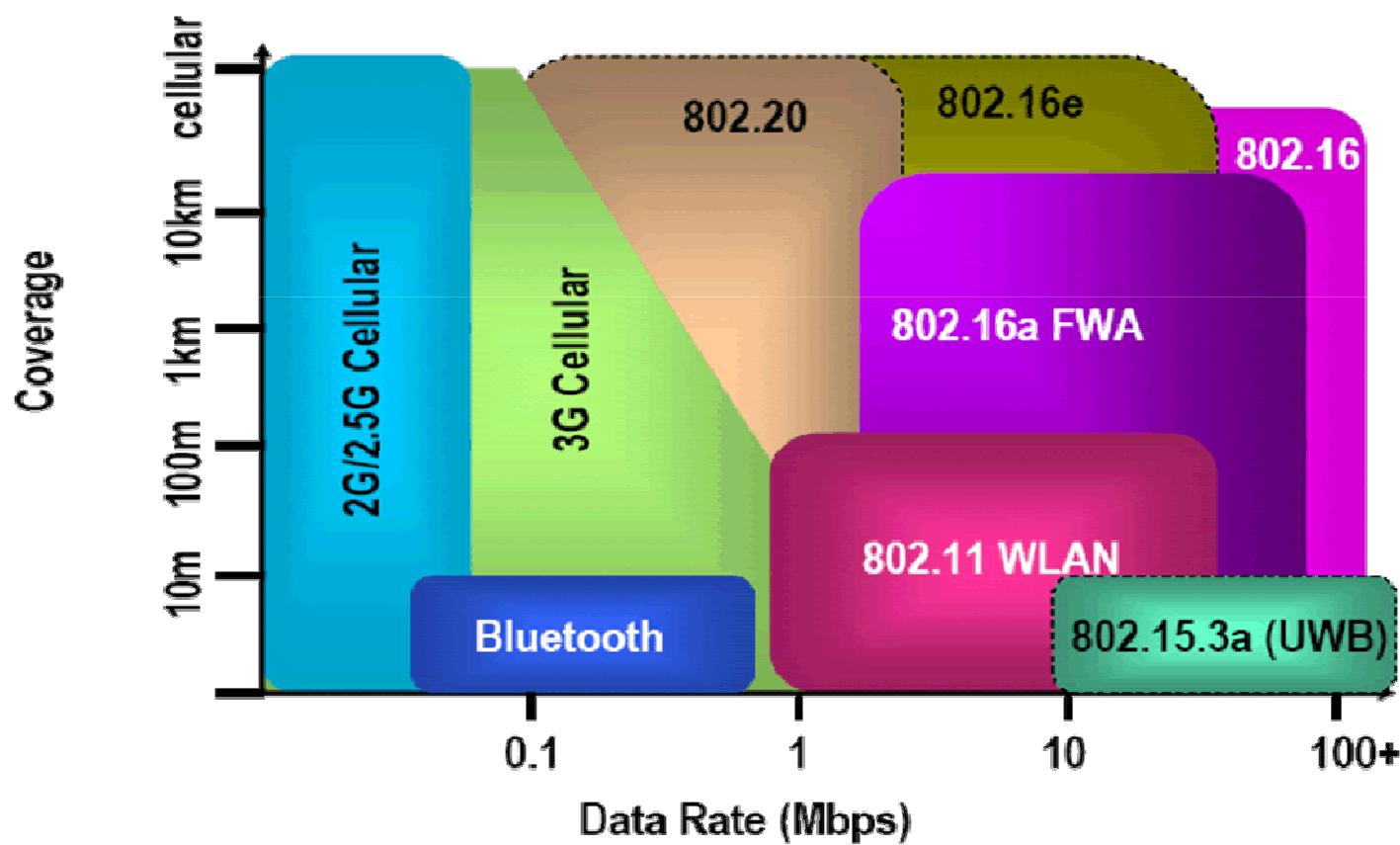
Nas próximas duas aulas...

- MACs de Redes sem Fio
 - rede de celulares
 - redes de WPAN (bluetooth)
 - redes WLAN (wifi)
 - redes WMAN (wimax)
 - etc

Abrangência Wireless



Cobertura X Taxa de transmissão



Provinha – 06.10.2009

- Escolhido um canal de transmissão, é ainda possível haver colisões no tráfego de uma célula?
- Um dispositivo móvel nota que o sinal recebido está diminuindo. Pode-se concluir que ele esteja se afastando do AP?
- Compare os campos de um frame 802.3 com um de 802.11. Porque são tão diferentes? Comente 3 diferenças básicas.
- Porque um mecanismo de aviso de recebimento (ACK) é mais importante em wireless do que em ethernet?
- Seria possível utilizar um esquema de cell splitting para melhorar o acesso WiFi em áreas de grande demanda? O que seria preciso fazer?

O Sistema Telefônico Móvel

- Telefones Móveis da Primeira Geração:
Voz Analógica
- Telefones Móveis da Segunda Geração:
Voz Digital
- Telefones Móveis da Terceira Geração:
Voz e Dados Digitais

Cellular Network Organization

- Use multiple low-power transmitters (100 W or less)
- Areas divided into cells
 - Each served by its own antenna
 - Served by base station consisting of transmitter, receiver, and control unit
 - Band of frequencies allocated
 - Cells set up such that antennas of all neighbors are equidistant (hexagonal pattern)

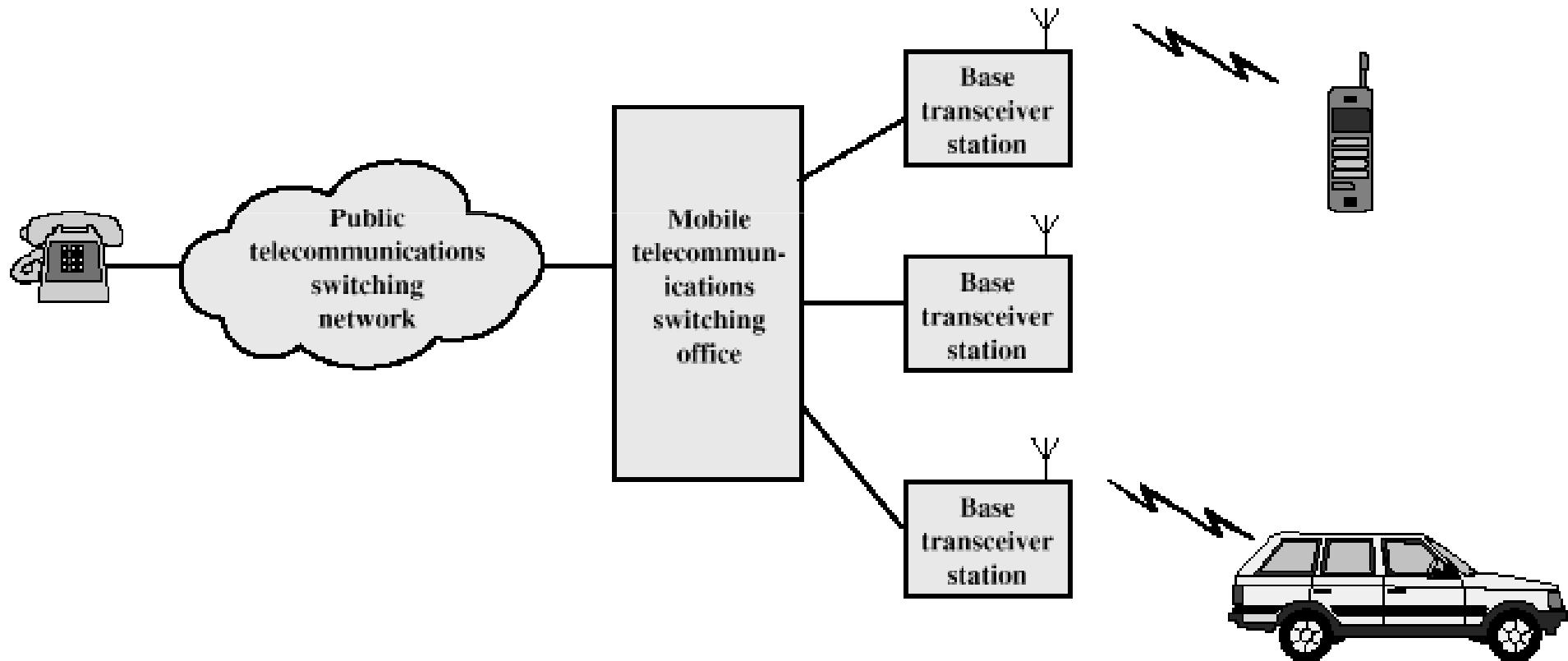
Frequency Reuse

- Adjacent cells assigned different frequencies to avoid interference or crosstalk
- Objective is to reuse frequency in nearby cells
 - 10 to 50 frequencies assigned to each cell
 - Transmission power controlled to limit power at that frequency escaping to adjacent cells
 - The issue is to determine how many cells must intervene between two cells using the same frequency

Approaches to Cope with Increasing Capacity

- Adding new channels
- Frequency borrowing – frequencies are taken from adjacent cells by congested cells
- Cell splitting – cells in areas of high usage can be split into smaller cells
- Cell sectoring – cells are divided into a number of wedge-shaped sectors, each with their own set of channels
- Microcells – antennas move to buildings, hills, and lamp posts

Cellular System Overview



Cellular Systems Terms

- Base Station (BS) – includes an antenna, a controller, and a number of receivers
- Mobile telecommunications switching office (MTSO) – connects calls between mobile units
- Two types of channels available between mobile unit and BS
 - Control channels – used to exchange information having to do with setting up and maintaining calls
 - Traffic channels – carry voice or data connection between users

Steps in an MTSO Controlled Call between Mobile Users

- Mobile unit initialization
- Mobile-originated call
- Paging
- Call accepted
- Ongoing call
- Handoff

Additional Functions in an MTSO Controlled Call

- Call blocking
- Call termination
- Call drop
- Calls to/from fixed and remote mobile subscriber

Mobile Radio Propagation Effects

- Signal strength
 - Must be strong enough between base station and mobile unit to maintain signal quality at the receiver
 - Must not be so strong as to create too much cochannel interference with channels in another cell using the same frequency band
- Fading
 - Signal propagation effects may disrupt the signal and cause errors

Handoff Performance Metrics

- Cell blocking probability – probability of a new call being blocked
- Call dropping probability – probability that a call is terminated due to a handoff
- Call completion probability – probability that an admitted call is not dropped before it terminates
- Probability of unsuccessful handoff – probability that a handoff is executed while the reception conditions are inadequate

Handoff Performance Metrics

- Handoff blocking probability – probability that a handoff cannot be successfully completed
- Handoff probability – probability that a handoff occurs before call termination
- Rate of handoff – number of handoffs per unit time
- Interruption duration – duration of time during a handoff in which a mobile is not connected to either base station
- Handoff delay – distance the mobile moves from the point at which the handoff should occur to the point at which it does occur

Handoff Strategies Used to Determine Instant of Handoff

- Relative signal strength
- Relative signal strength with threshold
- Relative signal strength with hysteresis
- Relative signal strength with hysteresis and threshold
- Prediction techniques

Power Control

- Design issues making it desirable to include dynamic power control in a cellular system
 - Received power must be sufficiently above the background noise for effective communication
 - Desirable to minimize power in the transmitted signal from the mobile
 - Reduce cochannel interference, alleviate health concerns, save battery power
 - In SS systems using CDMA, it's desirable to equalize the received power level from all mobile units at the BS

Types of Power Control

- Open-loop power control
 - Depends solely on mobile unit
 - No feedback from BS
 - Not as accurate as closed-loop, but can react quicker to fluctuations in signal strength
- Closed-loop power control
 - Adjusts signal strength in reverse channel based on metric of performance
 - BS makes power adjustment decision and communicates to mobile on control channel

Traffic Intensity

- Load presented to a system:

$$A = \lambda h$$

- λ = mean rate of calls attempted per unit time
- h = mean holding time per successful call
- A = average number of calls arriving during average holding period, for normalized λ

Factors that Determine the Nature of the Traffic Model

- Manner in which blocked calls are handled
 - Lost calls delayed (LCD) – blocked calls put in a queue awaiting a free channel
 - Blocked calls rejected and dropped
 - Lost calls cleared (LCC) – user waits before another attempt
 - Lost calls held (LCH) – user repeatedly attempts calling
- Number of traffic sources
 - Whether number of users is assumed to be finite or infinite

Mobile Station

- Mobile station communicates across Um interface (air interface) with base station transceiver in same cell as mobile unit
- Mobile equipment (ME) – physical terminal, such as a telephone or PCS
 - ME includes radio transceiver, digital signal processors and subscriber identity module (SIM)
- GSM subscriber units are generic until SIM is inserted
 - SIMs roam, not necessarily the subscriber devices

Base Station Subsystem (BSS)

- BSS consists of base station controller and one or more base transceiver stations (BTS)
- Each BTS defines a single cell
 - Includes radio antenna, radio transceiver and a link to a base station controller (BSC)
- BSC reserves radio frequencies, manages handoff of mobile unit from one cell to another within BSS, and controls paging

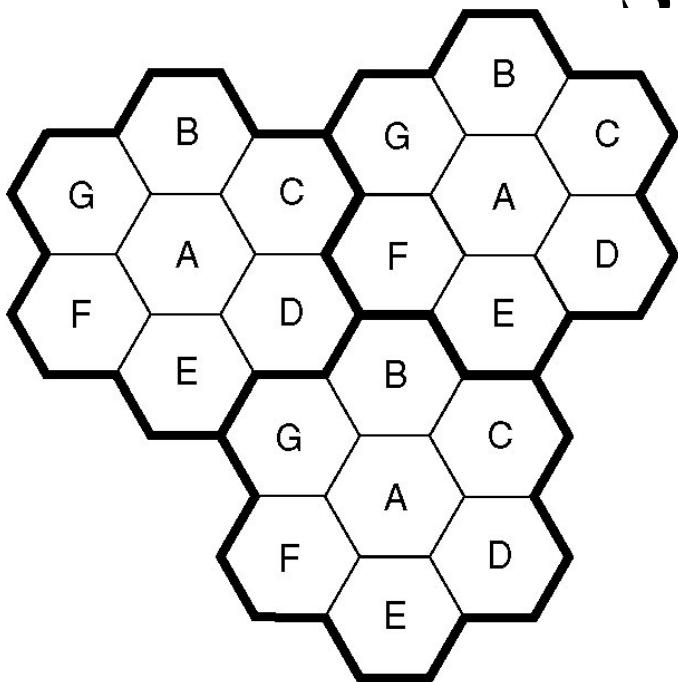
Network Subsystem (NS)

- NS provides link between cellular network and public switched telecommunications networks
 - Controls handoffs between cells in different BSSs
 - Authenticates users and validates accounts
 - Enables worldwide roaming of mobile users
- Central element of NS is the mobile switching center (MSC)

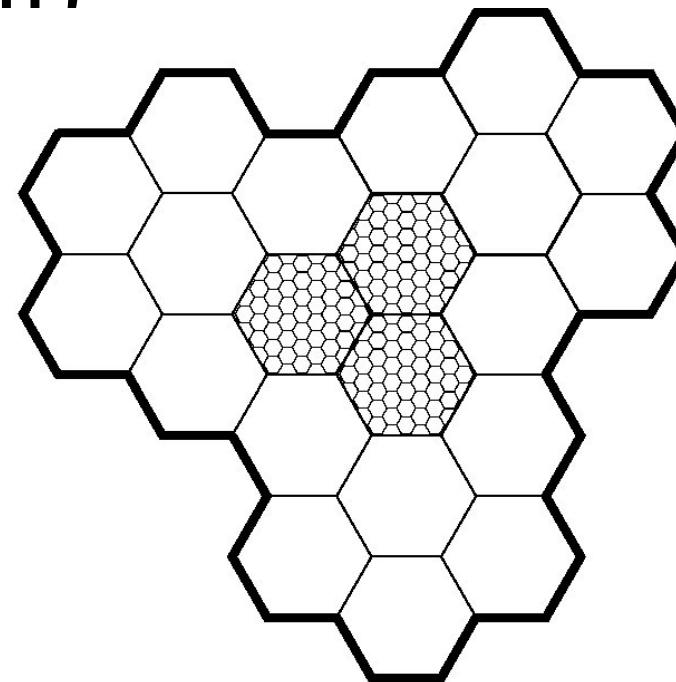
Mobile Switching Center (MSC) Databases

- Home location register (HLR) database – stores information about each subscriber that belongs to it
- Visitor location register (VLR) database – maintains information about subscribers currently physically in the region
- Authentication center database (AuC) – used for authentication activities, holds encryption keys
- Equipment identity register database (EIR) – keeps track of the type of equipment that exists at the mobile station

AMPS (Advanced Mobile Phone System)



(a)



(b)

- (a) As freqüências não são reutilizadas nas células adjacentes.
- (b) Para acrescentar usuários, podem ser utilizadas

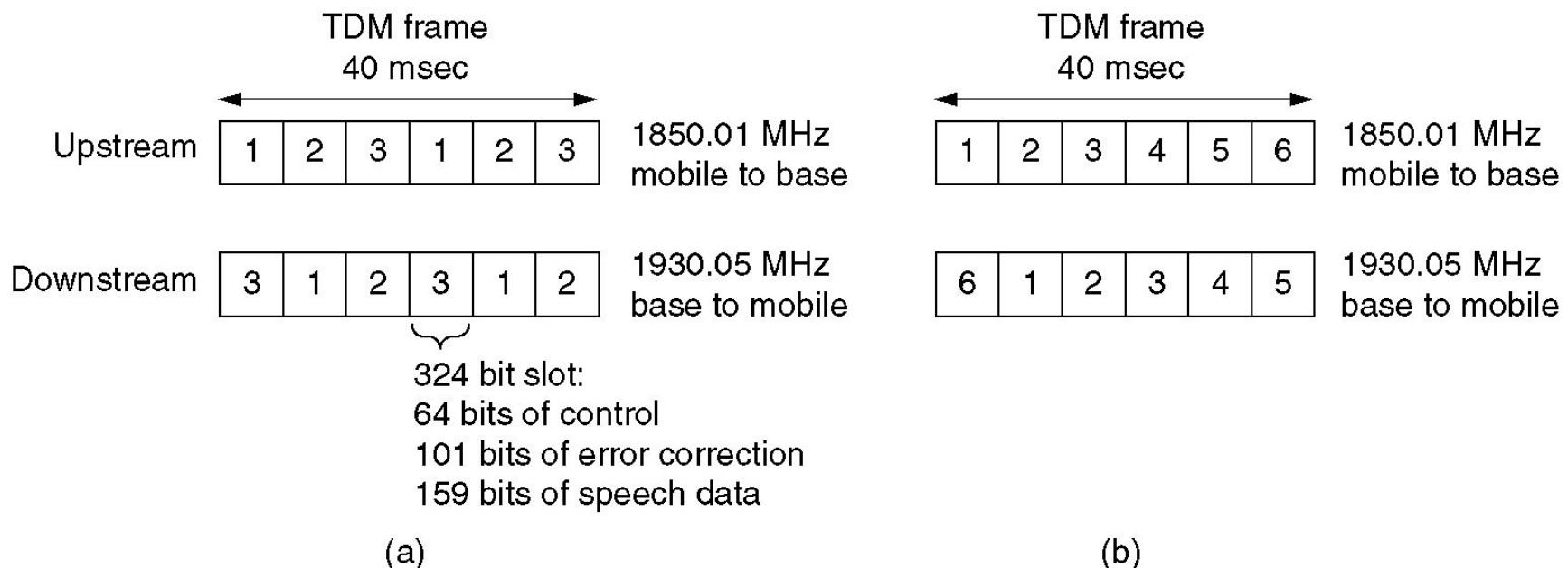
Categorias de Canais

Os 832 canais são divididos em quatro categorias:

- Controle (base para unidade móvel) para gerenciar o sistema
- *Paging* (base para unidade móvel) para alertar usuários para chamadas para eles
- Acesso (bidirecional) para estabelecimento da chamada e atribuição de canais
- Dados (bidirecional) para voz, fax ou dados

D-AMPS

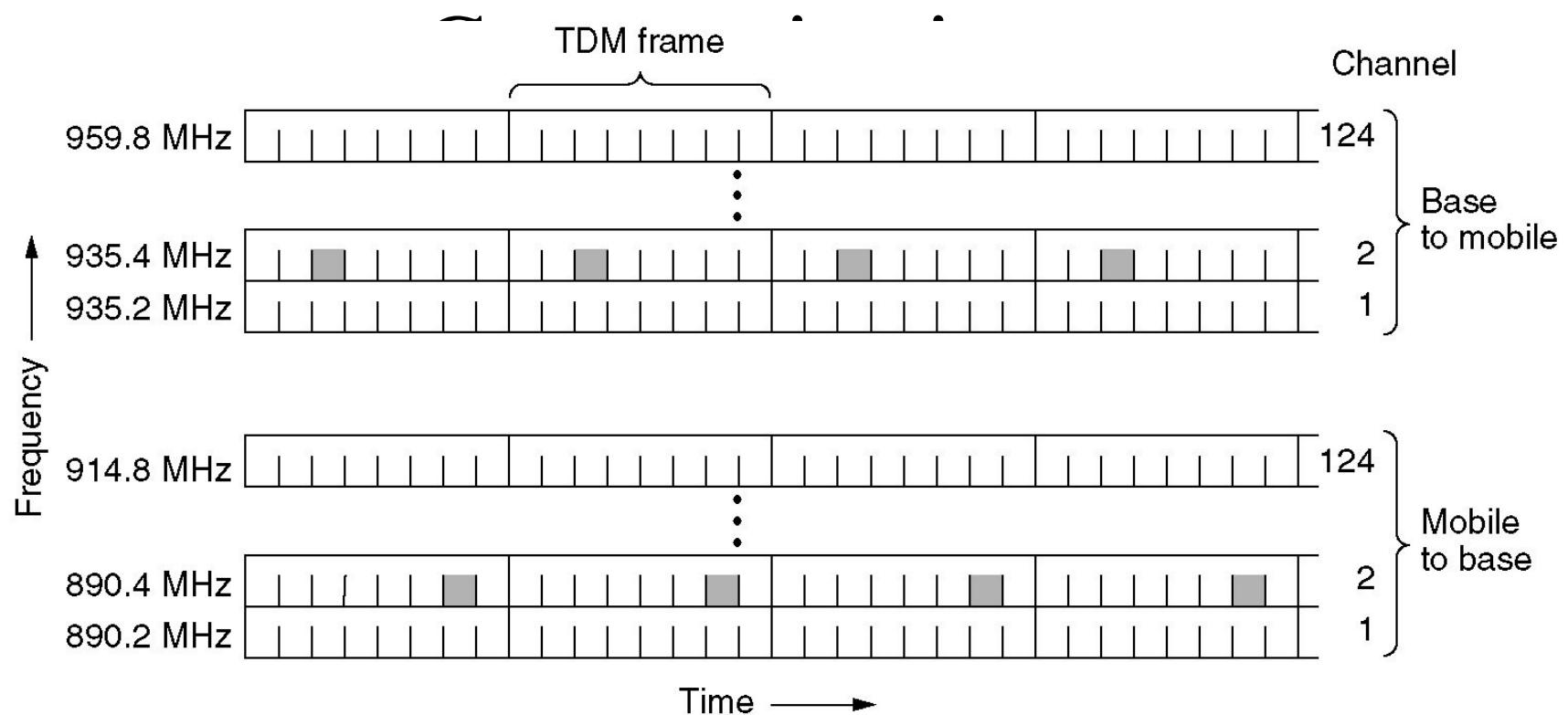
Digital Advanced Mobile Phone System



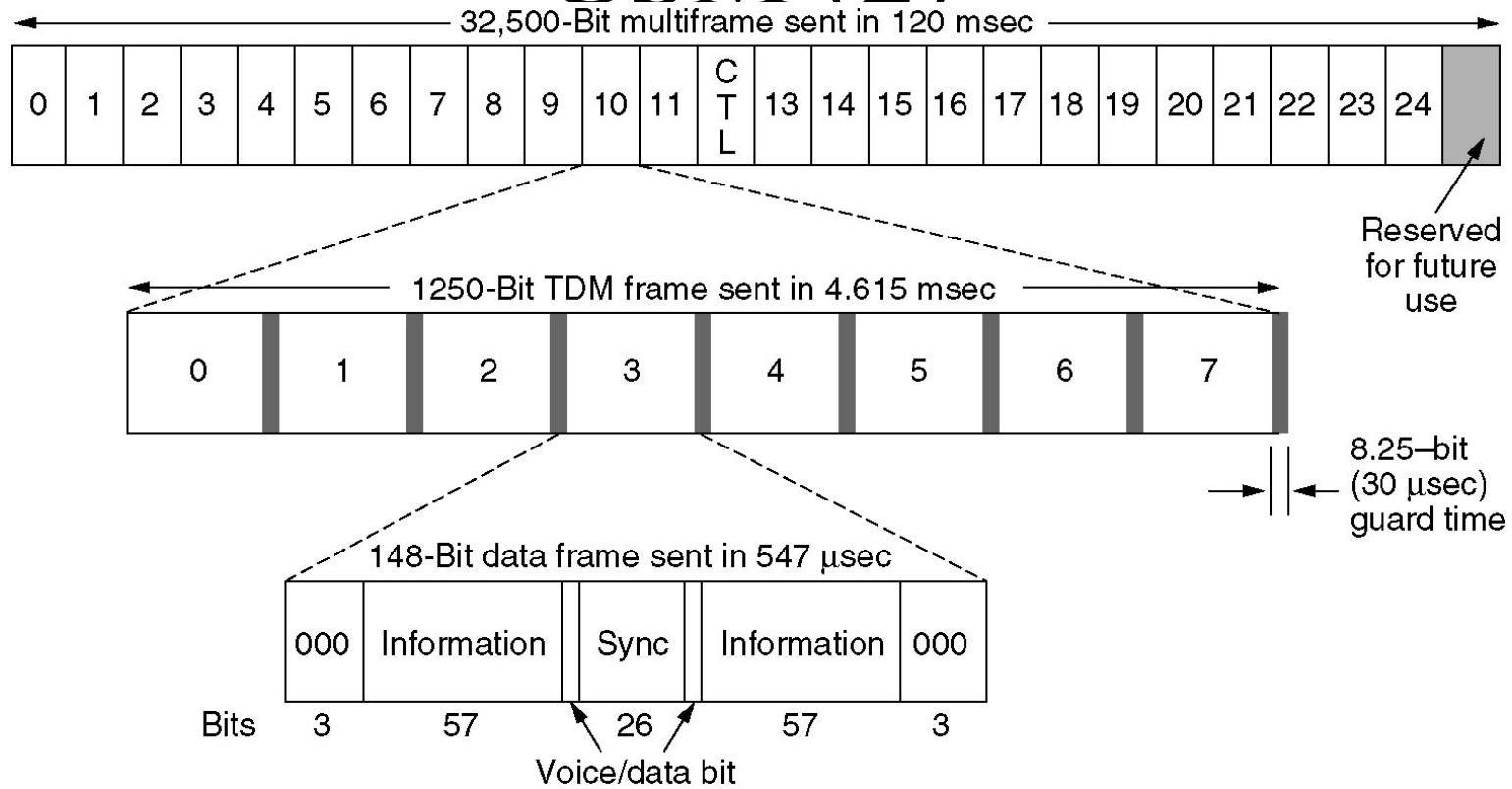
- (a) Um canal D-AMPS com três usuários.
(b) Um canal D-AMPS com seis usuários.

GSM

Global System for Mobile



GSM (2)



CDMA – Code Division Multiple

A: 0 0 0 1 1 0 1 1
B: 0 0 1 0 1 1 1 0
C: 0 1 0 1 1 1 0 0
D: 0 1 0 0 0 0 1 0

(a)

A: (-1 -1 -1 +1 +1 -1 +1 +1)
B: (-1 -1 +1 -1 +1 +1 +1 -1)
C: (-1 +1 -1 +1 +1 +1 -1 -1)
D: (-1 +1 -1 -1 -1 -1 +1 -1)

(b)

Six examples:

-- 1 -	C	$S_1 = (-1 +1 -1 +1 +1 +1 -1 -1)$
- 1 1 -	B + C	$S_2 = (-2 0 0 0 +2 +2 0 -2)$
1 0 --	A + B	$S_3 = (0 0 -2 +2 0 -2 0 +2)$
1 0 1 -	A + B + C	$S_4 = (-1 +1 -3 +3 +1 -1 -1 +1)$
1 1 1 1	A + B + C + D	$S_5 = (-4 0 -2 0 +2 0 +2 -2)$
1 1 0 1	A + B + C + D	$S_6 = (-2 -2 0 -2 0 -2 +4 0)$

(c)

$$\begin{aligned}S_1 \bullet C &= (1 +1 +1 +1 +1 +1 +1 +1)/8 = 1 \\S_2 \bullet C &= (2 +0 +0 +0 +2 +2 +0 +2)/8 = 1 \\S_3 \bullet C &= (0 +0 +2 +2 +0 -2 +0 -2)/8 = 0 \\S_4 \bullet C &= (1 +1 +3 +3 +1 -1 +1 -1)/8 = 1 \\S_5 \bullet C &= (4 +0 +2 +0 +2 +0 -2 +2)/8 = 1 \\S_6 \bullet C &= (2 -2 +0 -2 +0 -2 -4 +0)/8 = -1\end{aligned}$$

(d)

- (a) Seqüências binárias para quatro estações
- (b) Seqüências bipolares
- (c) Seis exemplos de transmissão
- (d) Recuperação do sinal da estação C

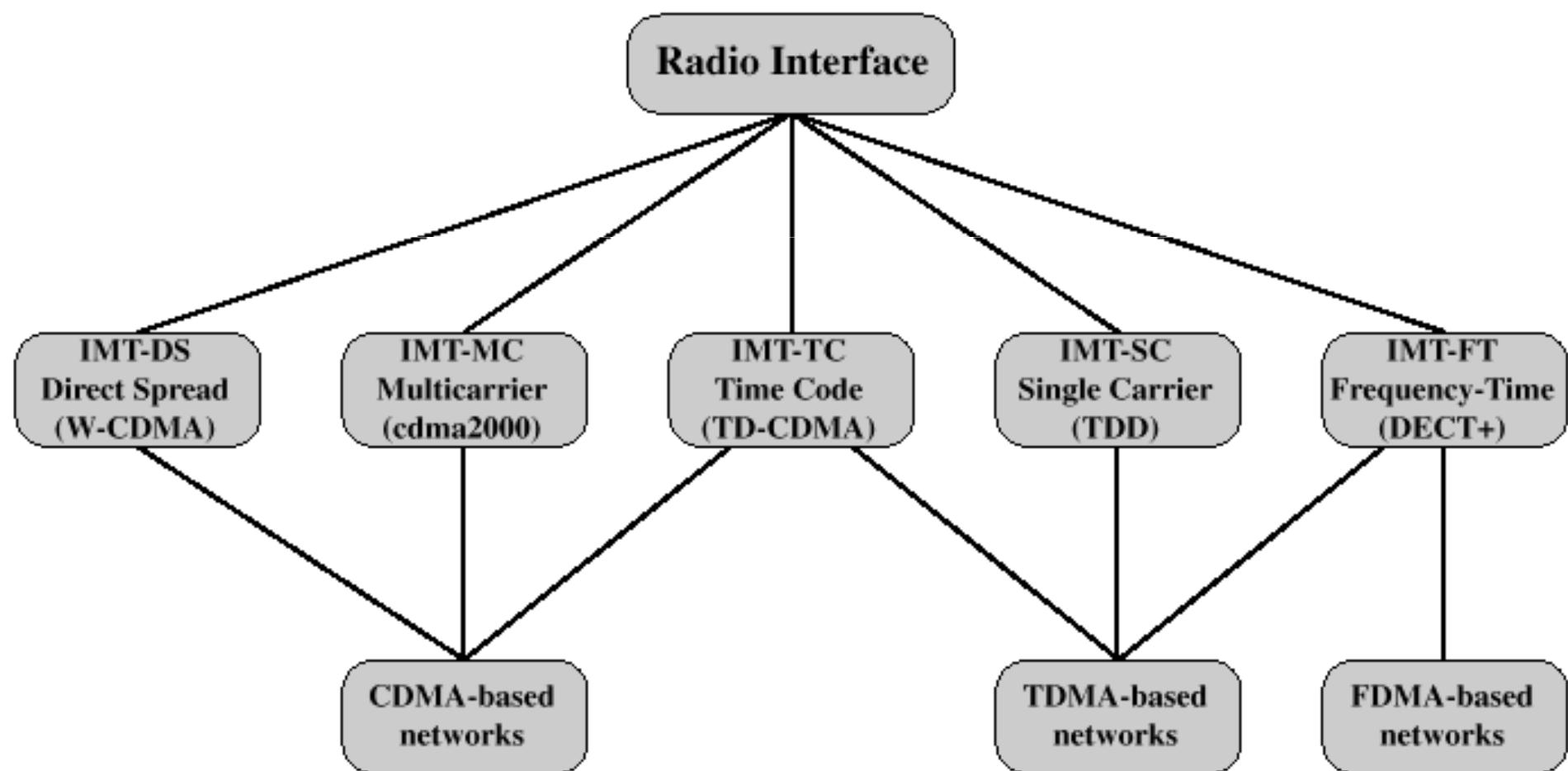
ITU's View of Third-Generation Capabilities

- Voice quality comparable to the public switched telephone network
- 144 kbps data rate available to users in high-speed motor vehicles over large areas
- 384 kbps available to pedestrians standing or moving slowly over small areas
- Support for 2.048 Mbps for office use
- Symmetrical / asymmetrical data transmission rates
- Support for both packet switched and circuit switched data services

ITU's View of Third-Generation Capabilities

- An adaptive interface to the Internet to reflect efficiently the common asymmetry between inbound and outbound traffic
- More efficient use of the available spectrum in general
- Support for a wide variety of mobile equipment
- Flexibility to allow the introduction of new services and technologies

Alternative Interfaces

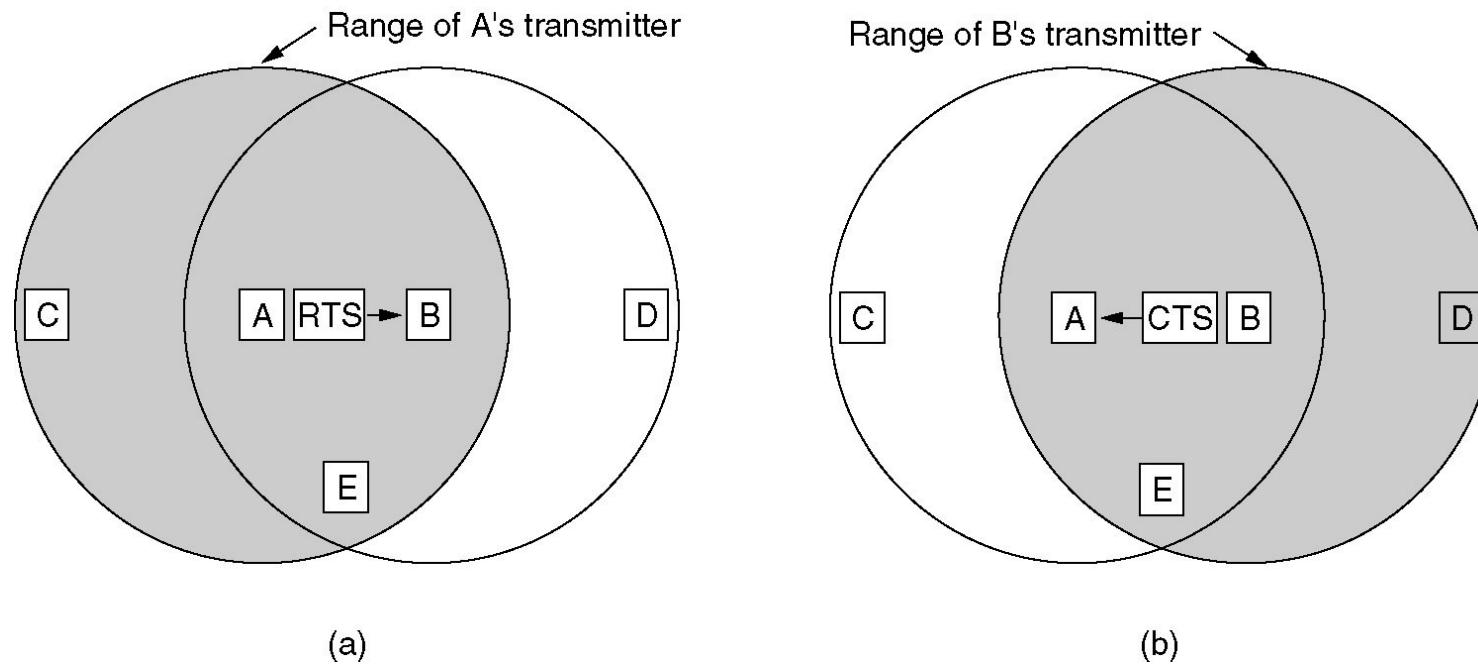


Telefones Móveis de Terceira Geração: Voz e Dados Digitais

Serviços básicos uma rede IMT-2000 deve fornecer

- Transmissão de voz em alta-qualidade
- Mensagens (substitui e-mail, fax, SMS, chat, etc.)
- Multimídia (música, vídeos, filmes, TV, etc.)
- Acesso à Internet (navegação web, com multimídia.)

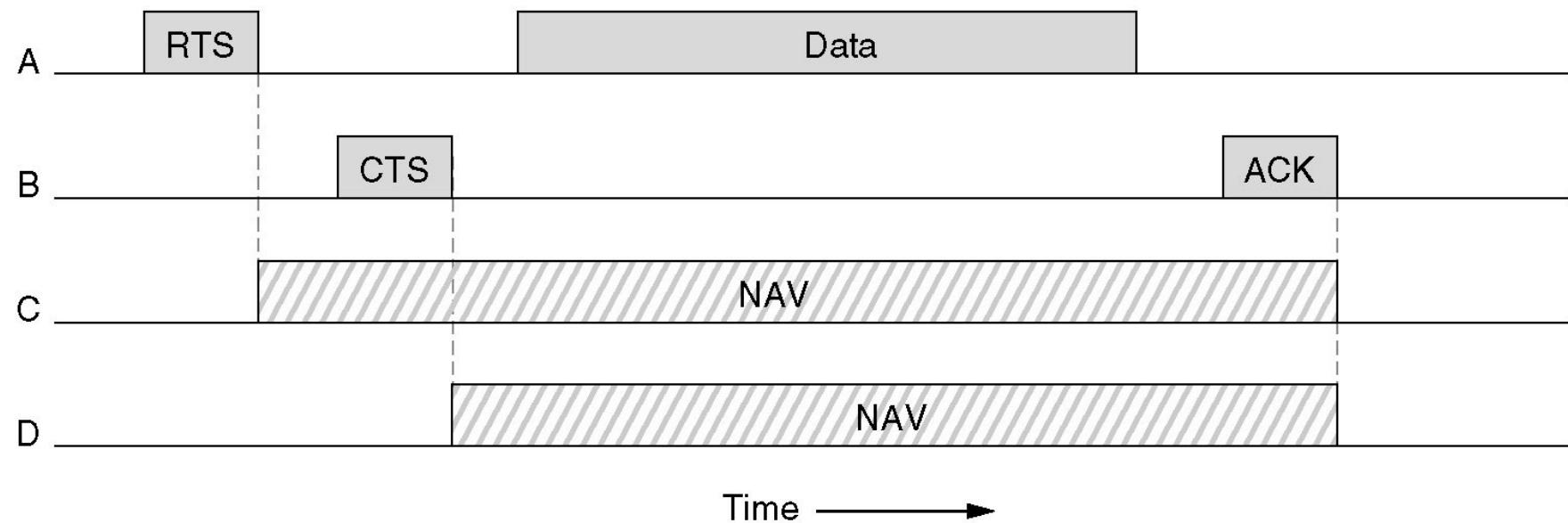
Protocolos de LAN sem Fio (2)



O protocolo MACA. (a) A enviando um RTS para B.
(b) B respondendo com um CTS para A.

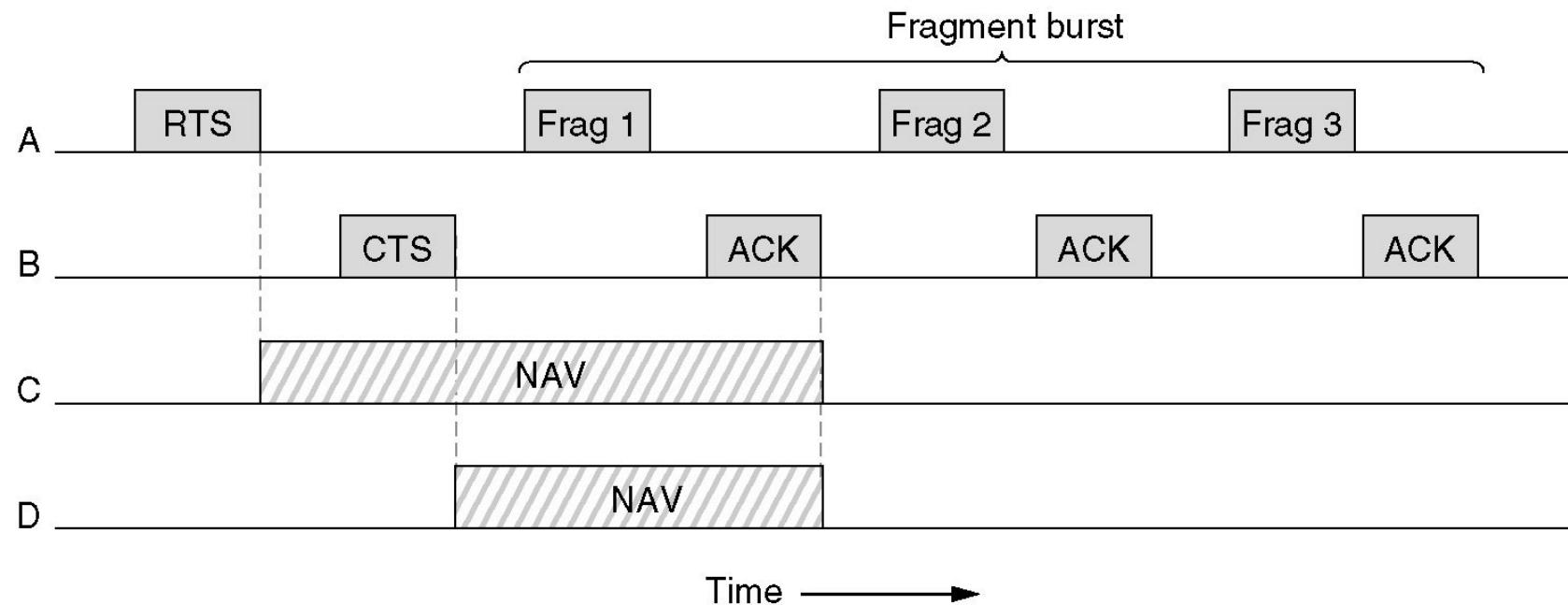
O Protocolo de Subcamada MAC

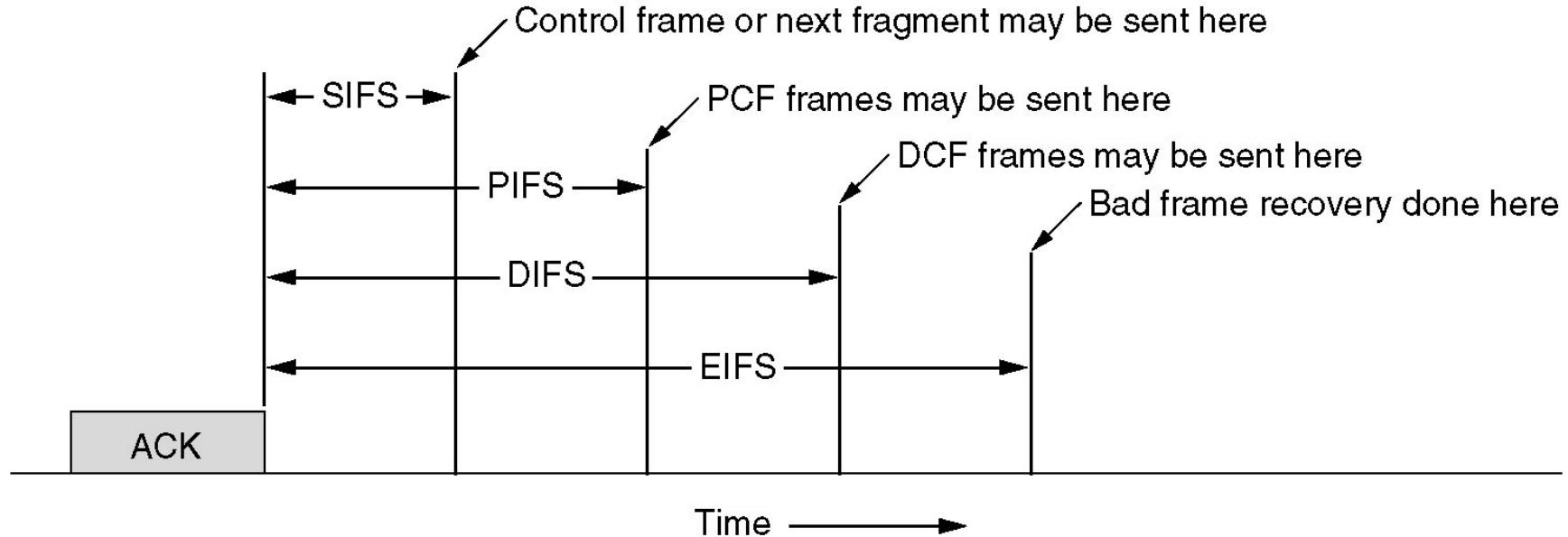
802.11



O Protocolo de Subcamada MAC

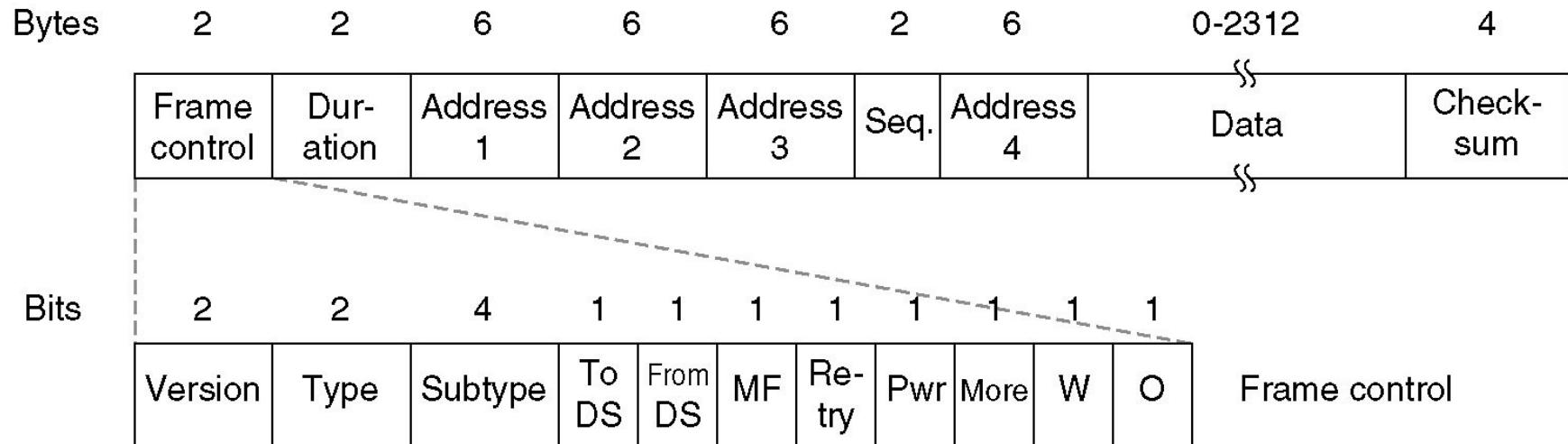
802.11



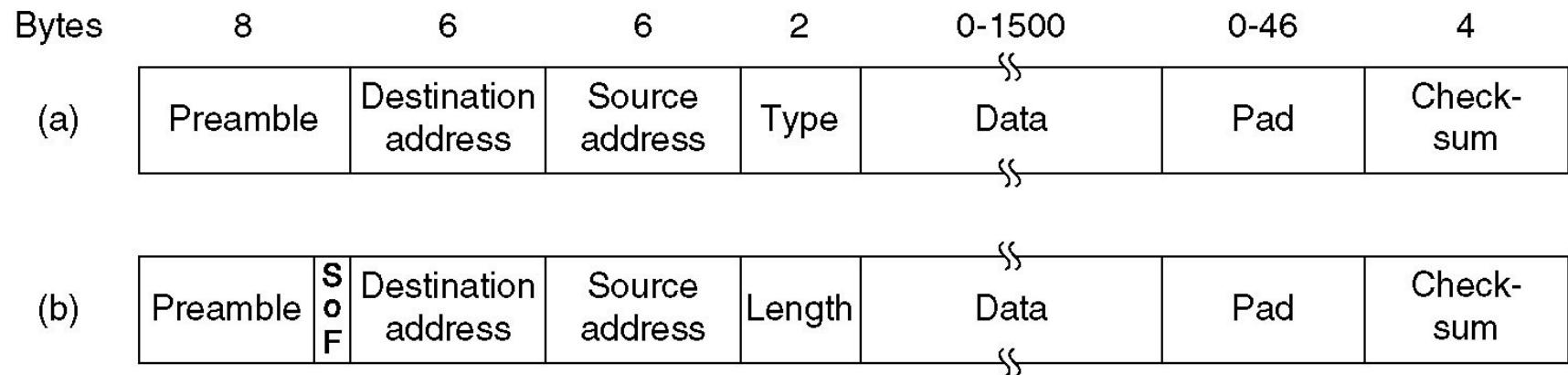


- **SIFS: Short InterFrame Spacing**
 - Usado para garantir prioridade para uma conversa (fragmentos), inclusive para o receiver enviar CTS ou ACK (control)
- **PIFS: PCF InterFrame Spacing**
 - A Estacao Base pode enviar um beacon ou poll frame (convite para quem quiser usar o meio)
- **DIFS: DCF InterFrame Spacing**
 - Qualquer estacao pode tentar alocar o canal para transmitir
 - Pode haver colisao
- **EIFS: Extended InterFrame Spacing**
 - Usado para reportar recebimento de frames danificados

A Estrutura de Quadro 802.11



Compare com o quadro Ethernet



Formatos de quadro. (a) DIX Ethernet, (b)
IEEE 802.3.

Serviços 802.11

Serviços de Distribuição

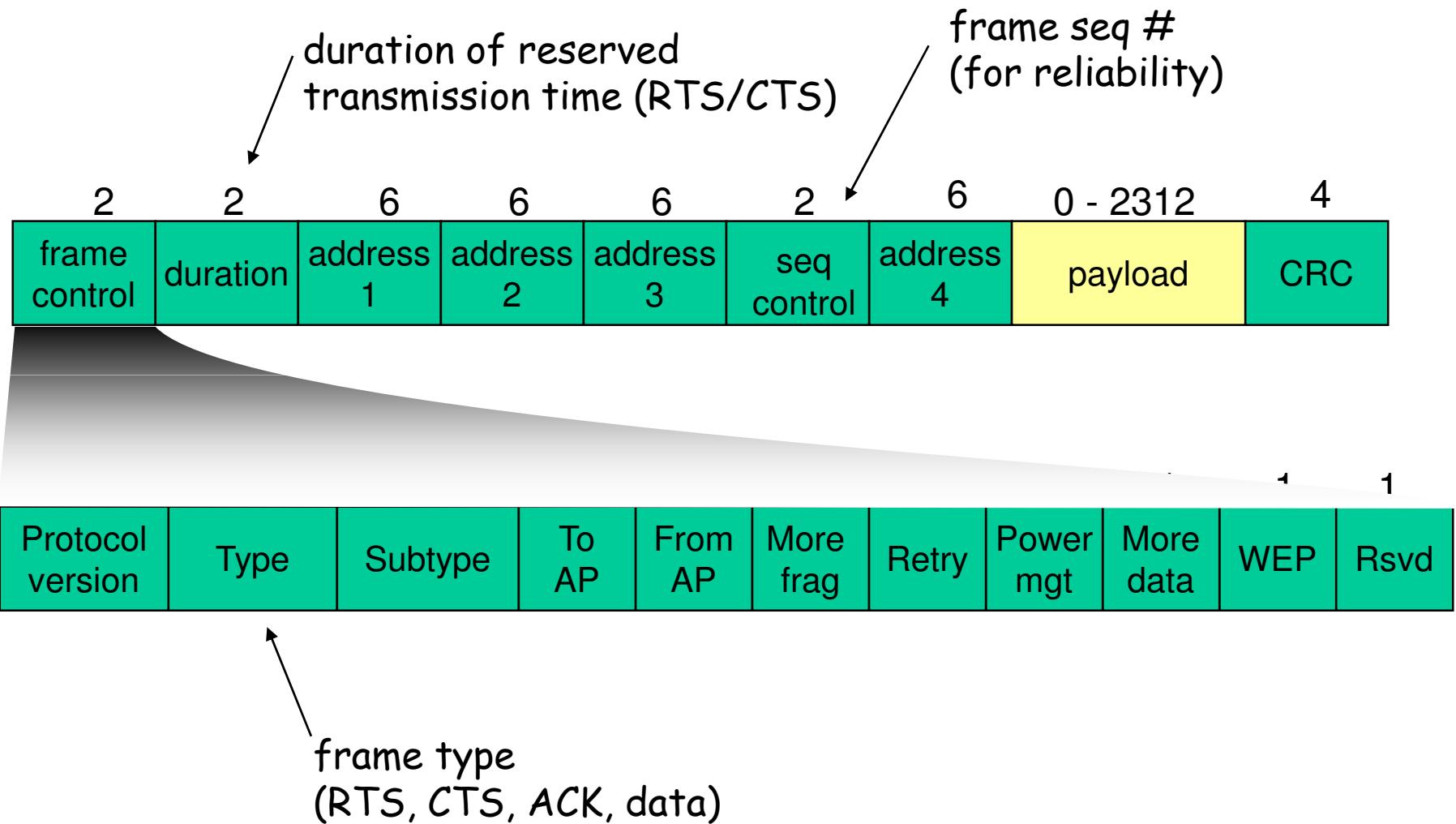
- Associação
- Desassociação
- Reassociação
- Distribuição
- Integração

Serviços 802.11

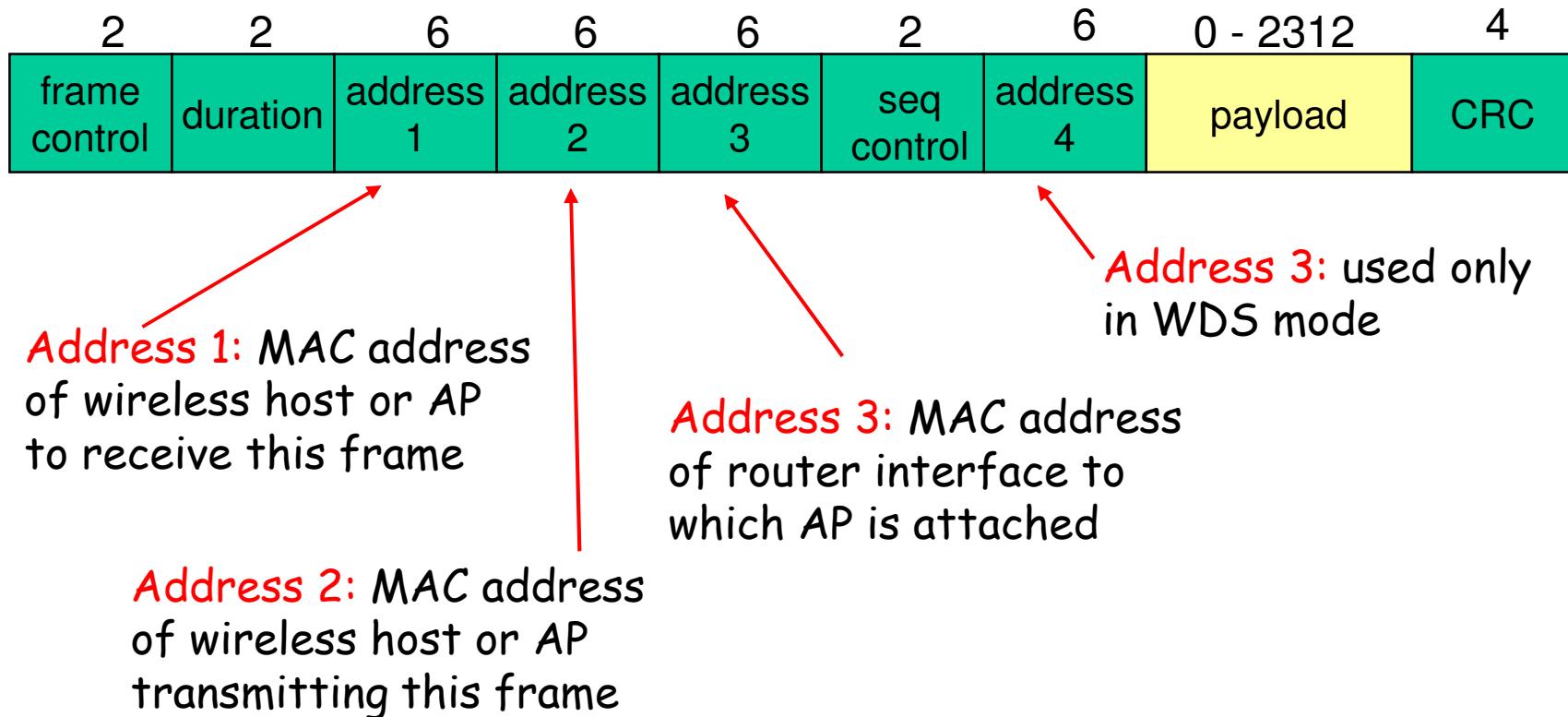
Serviços Intra-células

- Autenticação
- Desautenticação
- Privacidade
- Entrega de Dados

A Estrutura de Quadro 802.11



A Estrutura de Quadro 802.11: Enderessamento

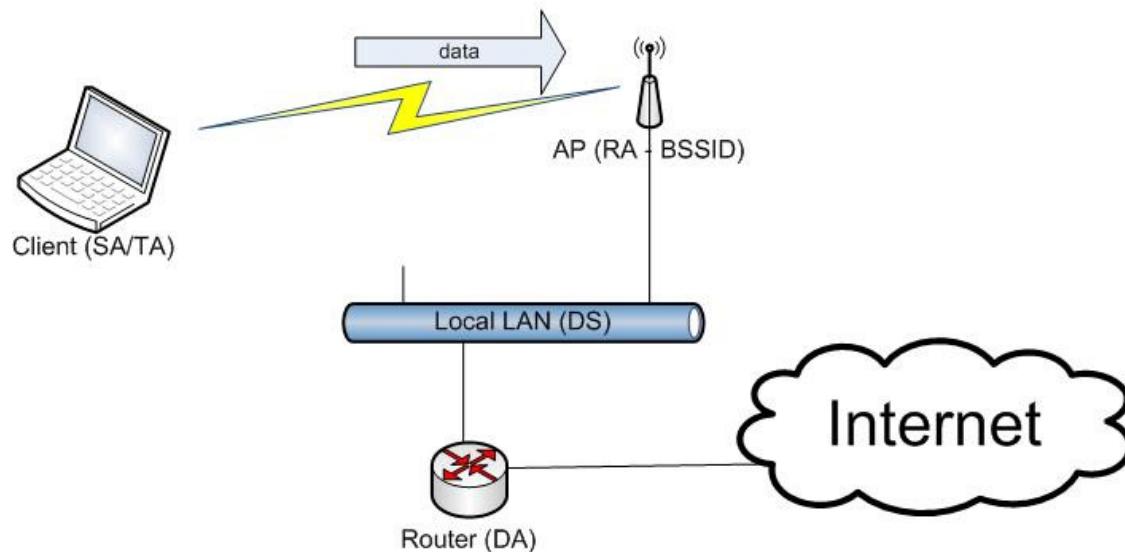


Endereços 802.11

To DS	From DS	Add 1	Add 2	Add 3	Add 4
0	0	DA	SA	BSSID	N/A
0	1	DA	BSSID	SA	N/A
1	0	BSSID	SA	DA	N/A
1	1	RA	TA	DA	SA

Endereços 802.11

To DS bit is set



To DS	From DS	Add 1	Add 2	Add 3	Add 4
0	0	DA	SA	BSSID	N/A
0	1	DA/RA	TA (BSSID)	SA	N/A
1	0	RA (BSSID)	SA/TA	DA	N/A
1	1	RA	TA	DA	SA

DA – Destination Address

BSSID – Network Identifier (MAC address in infra mode)

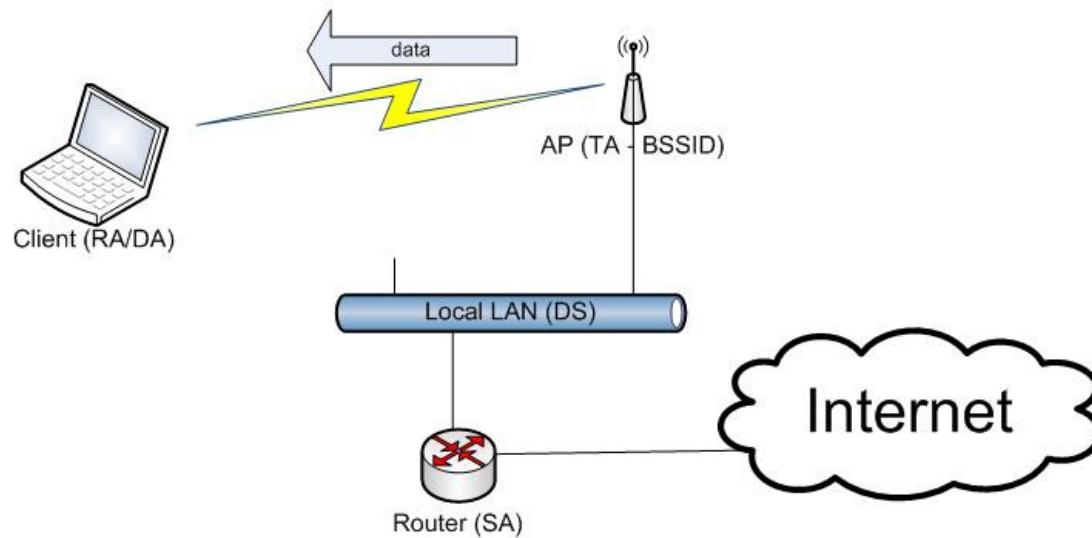
SA – Source Address

RA – Receiver Address

TA – Transmitter Address

Endereços 802.11

From DS bit is set



To DS	From DS	Add 1	Add 2	Add 3	Add 4
0	0	DA	SA	BSSID	N/A
0	1	DA/RA	TA (BSSID)	SA	N/A
1	0	RA (BSSID)	SA/TA	DA	N/A
1	1	RA	TA	DA	SA

DA – Destination Address

BSSID – Network Identifier (MAC address in infra mode)

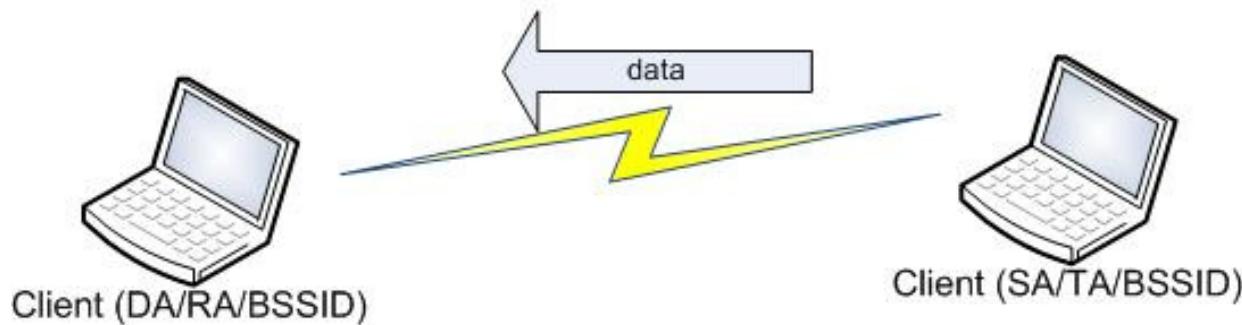
SA – Source Address

RA – Receiver Address

TA – Transmitter Address

Endereços 802.11

**From DS and To DS
are cleared (Ad-hoc)**



To DS	From DS	Add 1	Add 2	Add 3	Add 4
0	0	DA	SA	BSSID	N/A
0	1	DA/RA	TA (BSSID)	SA	N/A
1	0	RA (BSSID)	SA/TA	DA	N/A
1	1	RA	TA	DA	SA

DA – Destination Address

BSSID – Network Identifier (MAC address in infra mode)

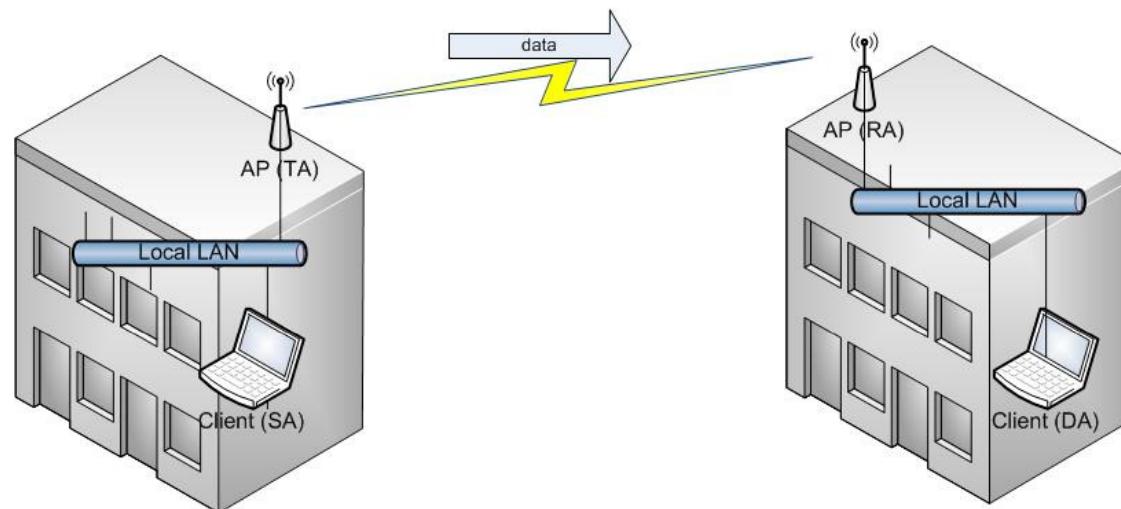
SA – Source Address

RA – Receiver Address

TA – Transmitter Address

Endereços 802.11

From DS and To DS are set (WDS)



To DS	From DS	Add 1	Add 2	Add 3	Add 4
0	0	DA	SA	BSSID	N/A
0	1	DA/RA	TA (BSSID)	SA	N/A
1	0	RA (BSSID)	SA/TA	DA	N/A
1	1	RA	TA	DA	SA

DA – Destination Address

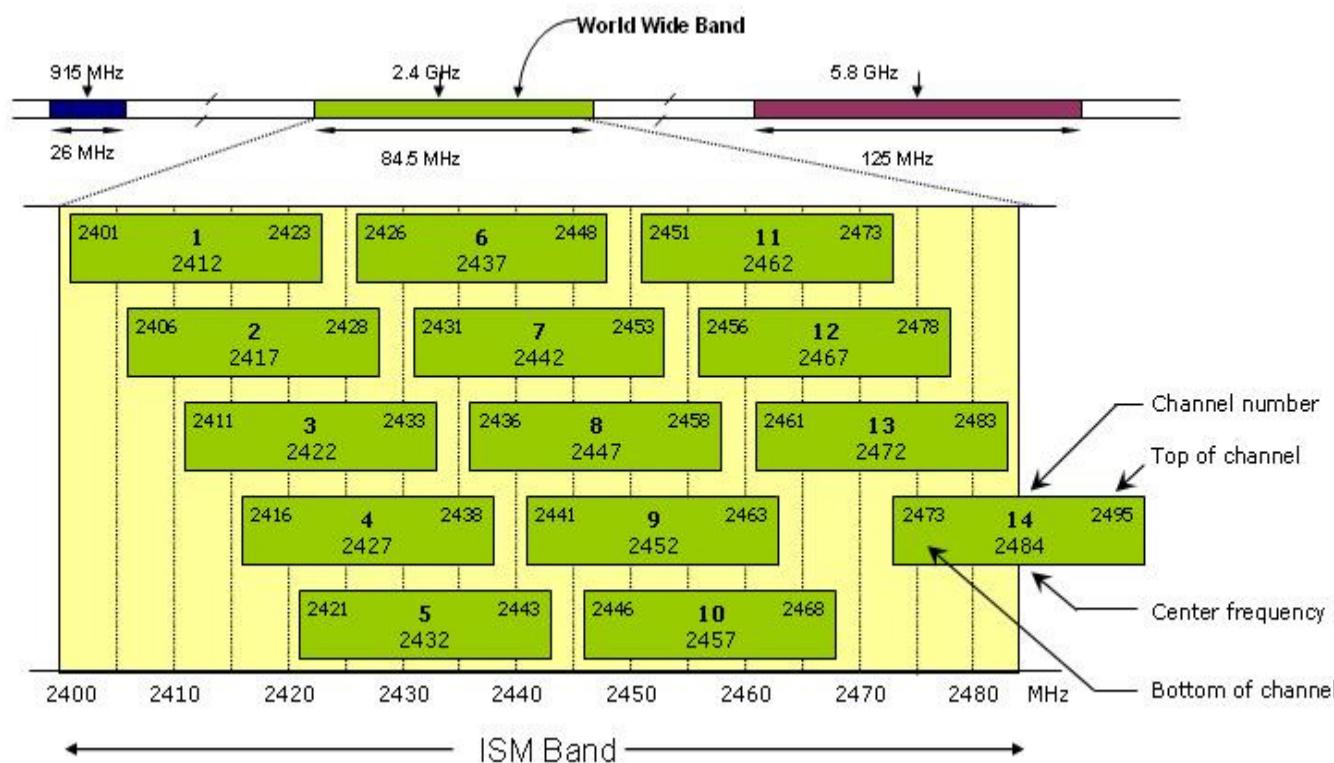
SA – Source Address

BSSID – Network Identifier (MAC address in infra mode)

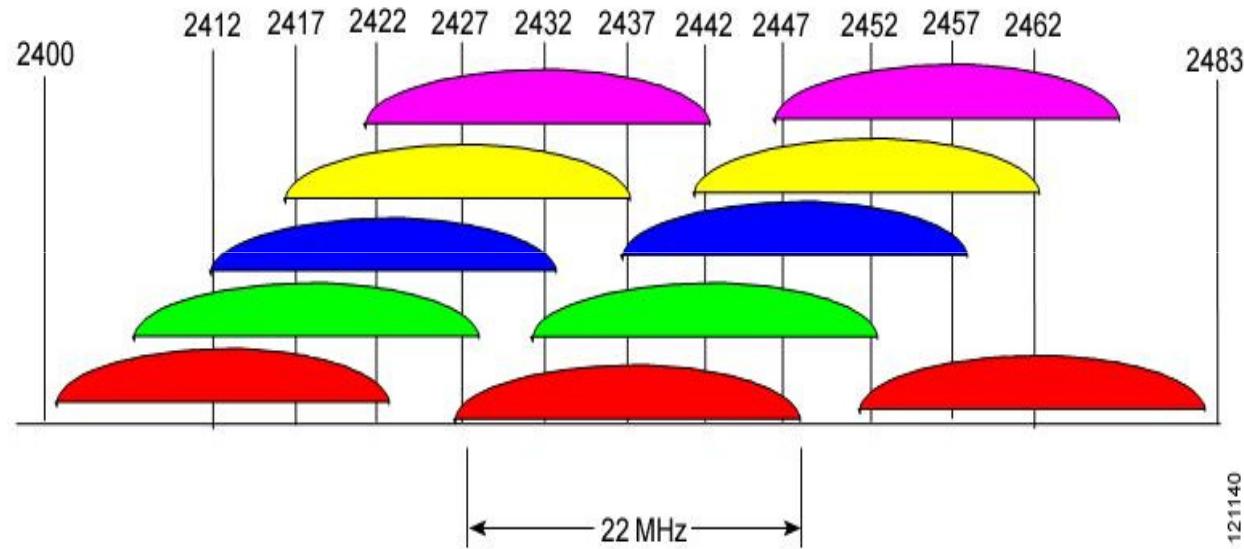
RA – Receiver Address

TA – Transmitter Address

Alocação de frequências no 802.11



Apenas canais frequências sem interferência



Serviços 802.11

Serviços de Distribuição

- Associação
- Desassociação
- Reassociação
- Distribuição
- Integração

Serviços 802.11

Serviços Intra-células

- Autenticação
- Desautenticação
- Privacidade
- Entrega de Dados

802.11 usa OFDM

- Orthogonal Frequency Division Multiplexing.
- Estudos começaram nos anos 70.
- Baseado no conceito de múltiplas portadoras.

OFDM

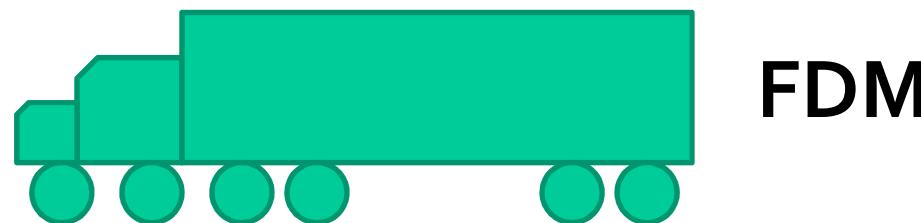
- A técnica de transmissão é muito utilizada em:
 - Sistemas de TV Digital
 - Redes Wireless 802.11 a/g/n e 802.16
 - xDSL

Idéia do Sistema OFDM

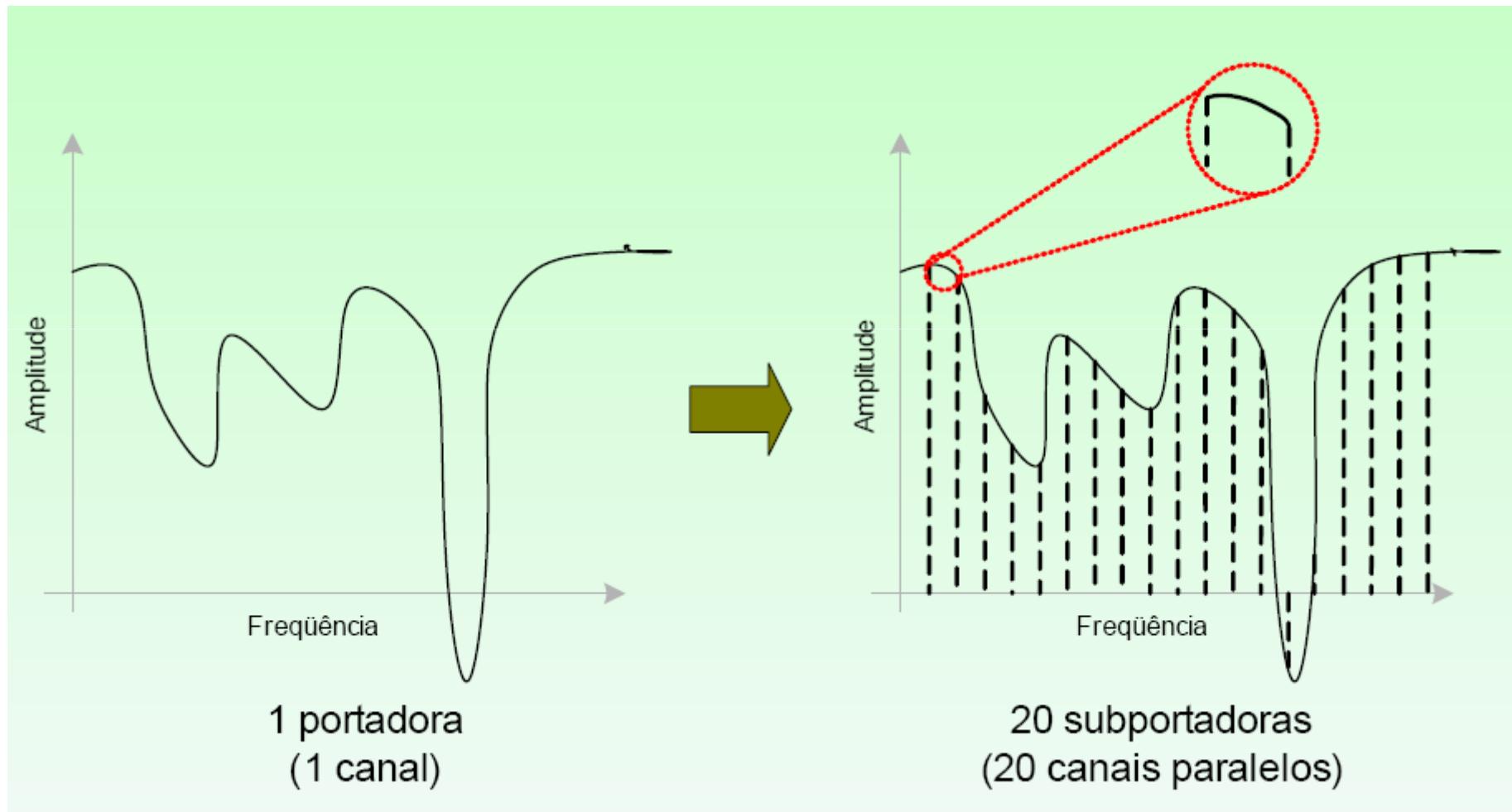
- Idéia Básica

- Uso de um grande número de sub-portadoras paralelas com baixa banda, instanciadas em uma única portadora de grande banda para transportar informações.

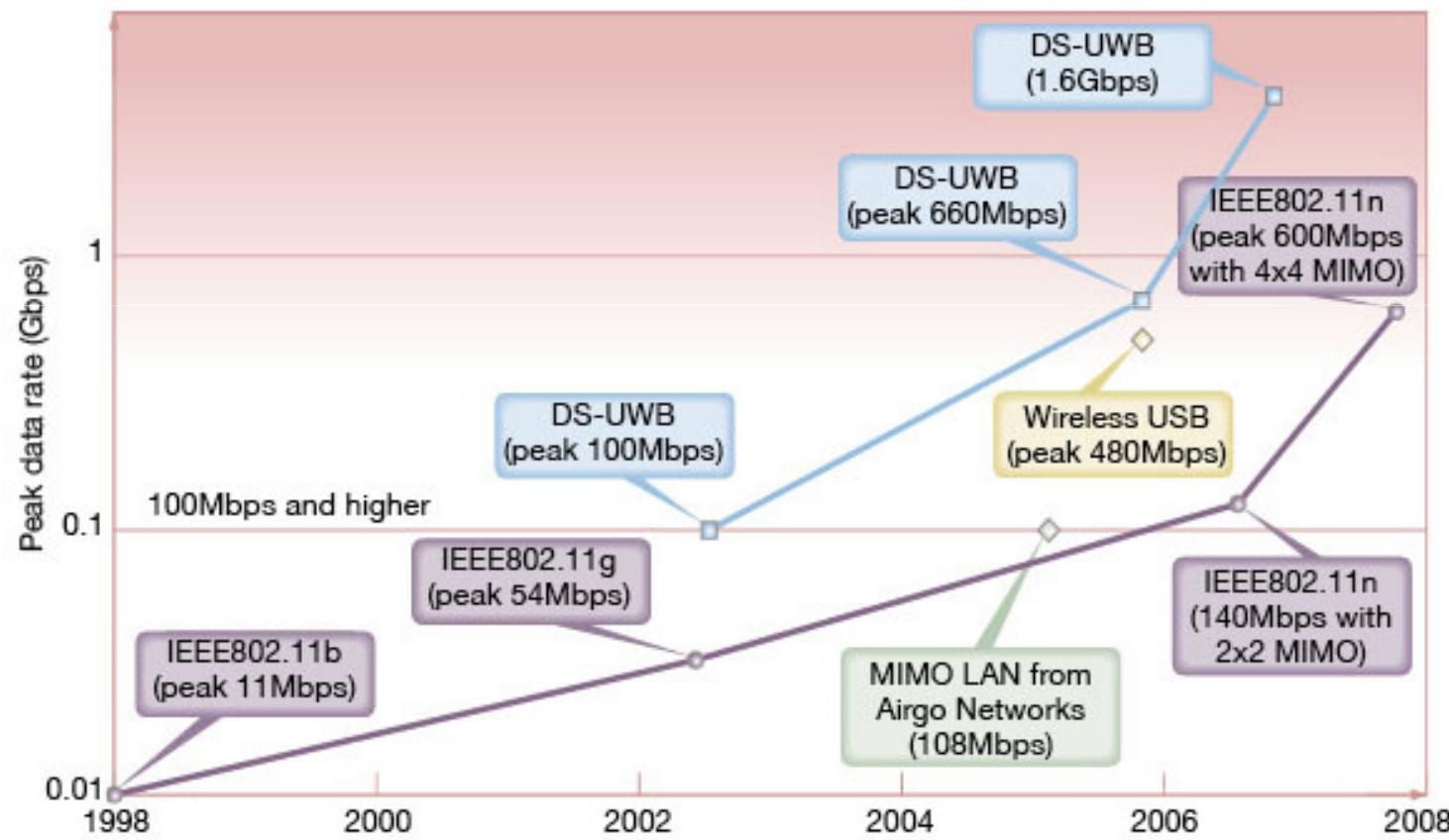
Idéia do Sistema OFDM



Idéia do Sistema OFDM

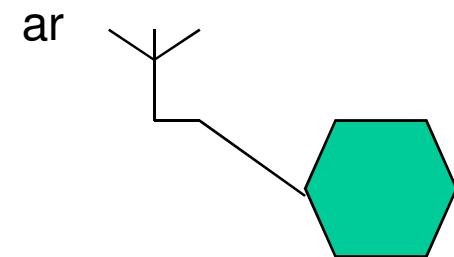
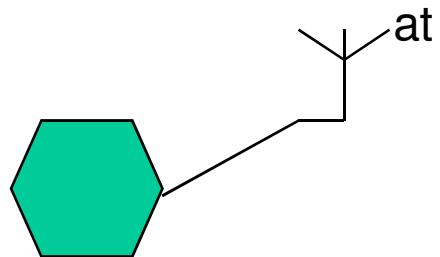


Sobre a tecnologia MIMO (802.11n)



Sobre a tecnologia MIMO

- SISO - Única entrada e única saída



Única antena para enviar e única antena para receber

Sobre a tecnologia MIMO

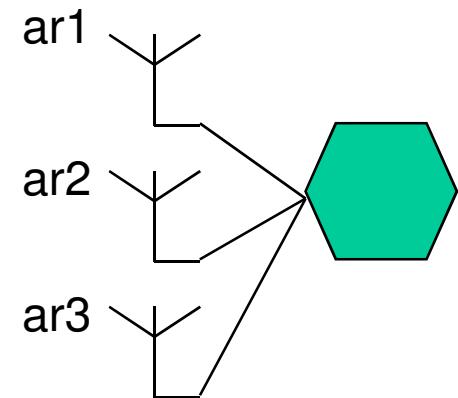
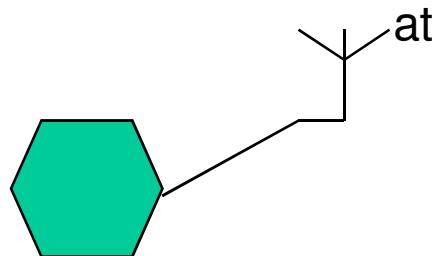
- SISO - Única entrada e única saída



Única antena para enviar e única antena para receber

Sobre a tecnologia MIMO

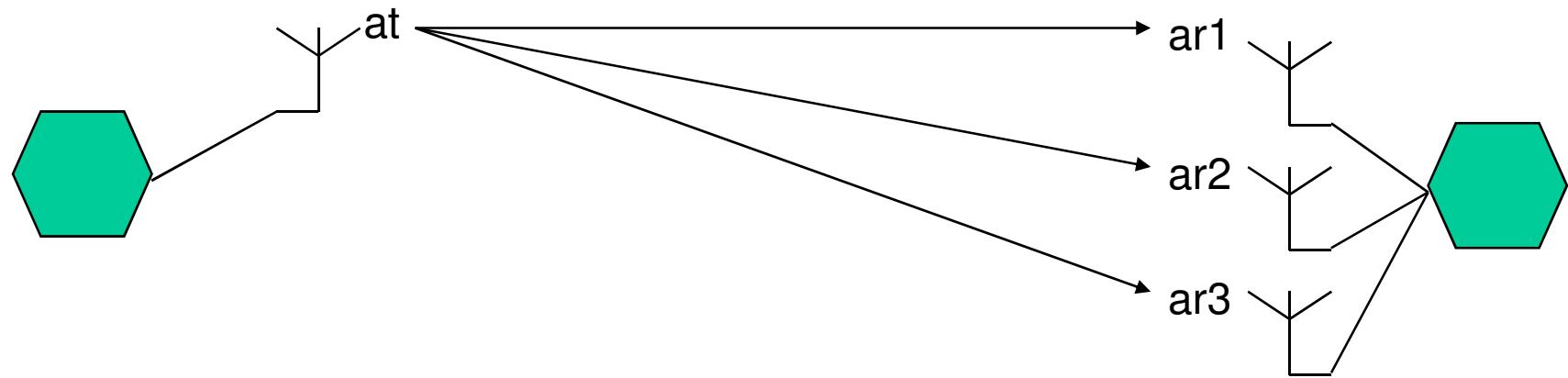
- SIMO - Única entrada e Múltiplas saídas



Única antena para transmitir e várias antenas para receber

Sobre a tecnologia MIMO

- SIMO - Única entrada e Múltiplas saídas



Única antena para transmitir e várias antena para receber

Sobre a tecnologia MIMO

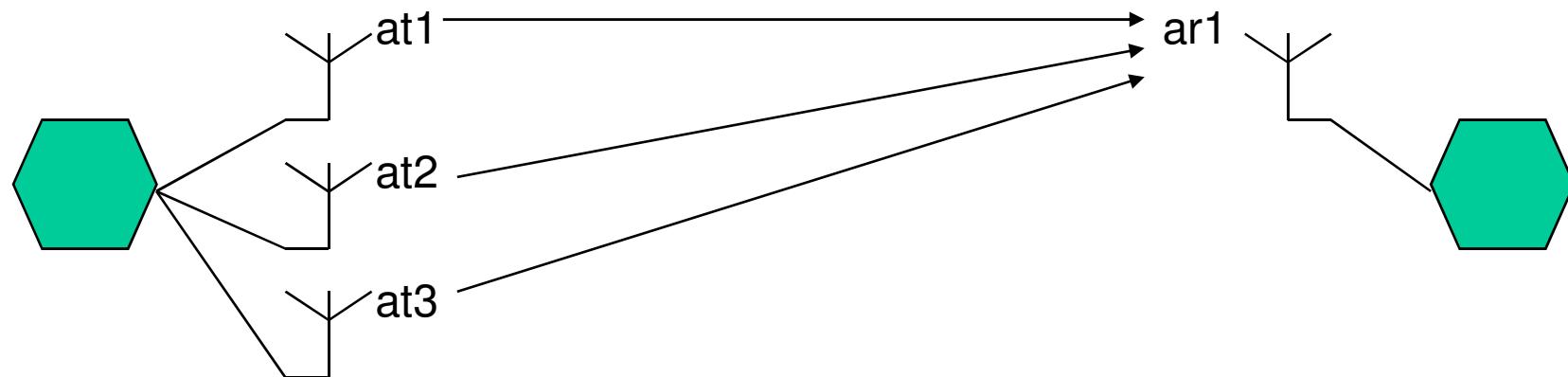
- MISO - Múltiplas entradas e única saída



Várias antenas para transmitir e única antena para receber

Sobre a tecnologia MIMO

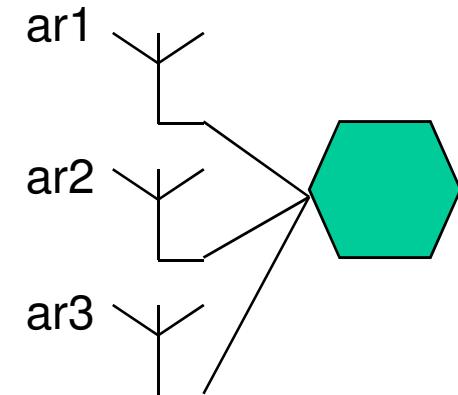
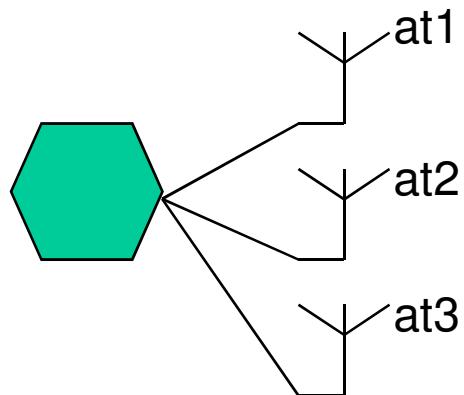
- MISO - Múltiplas entradas e única saída



Várias antenas para transmitir e única antena para receber

Sobre a tecnologia MIMO

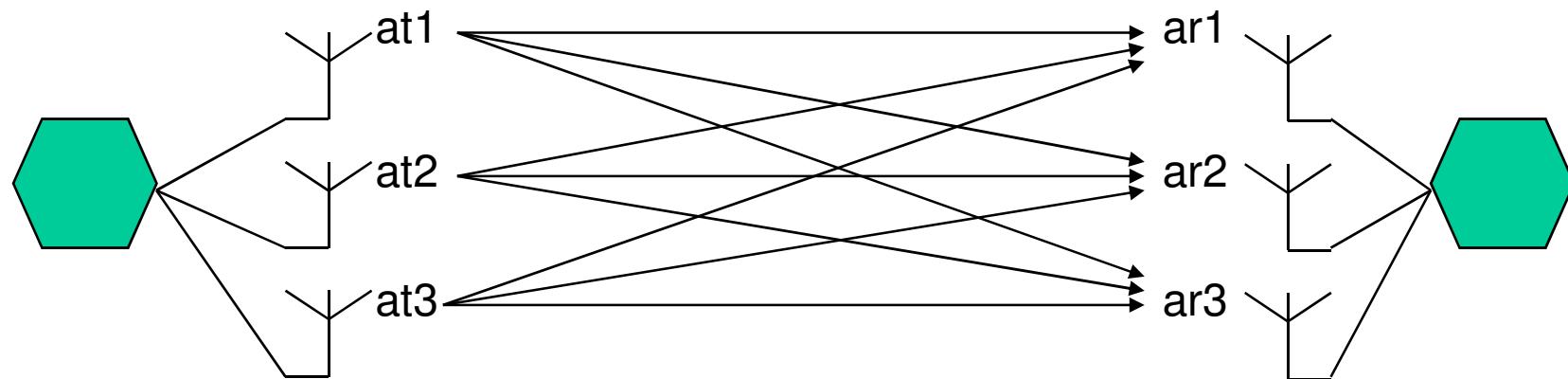
- MIMO - Múltiplas entradas e múltiplas saídas



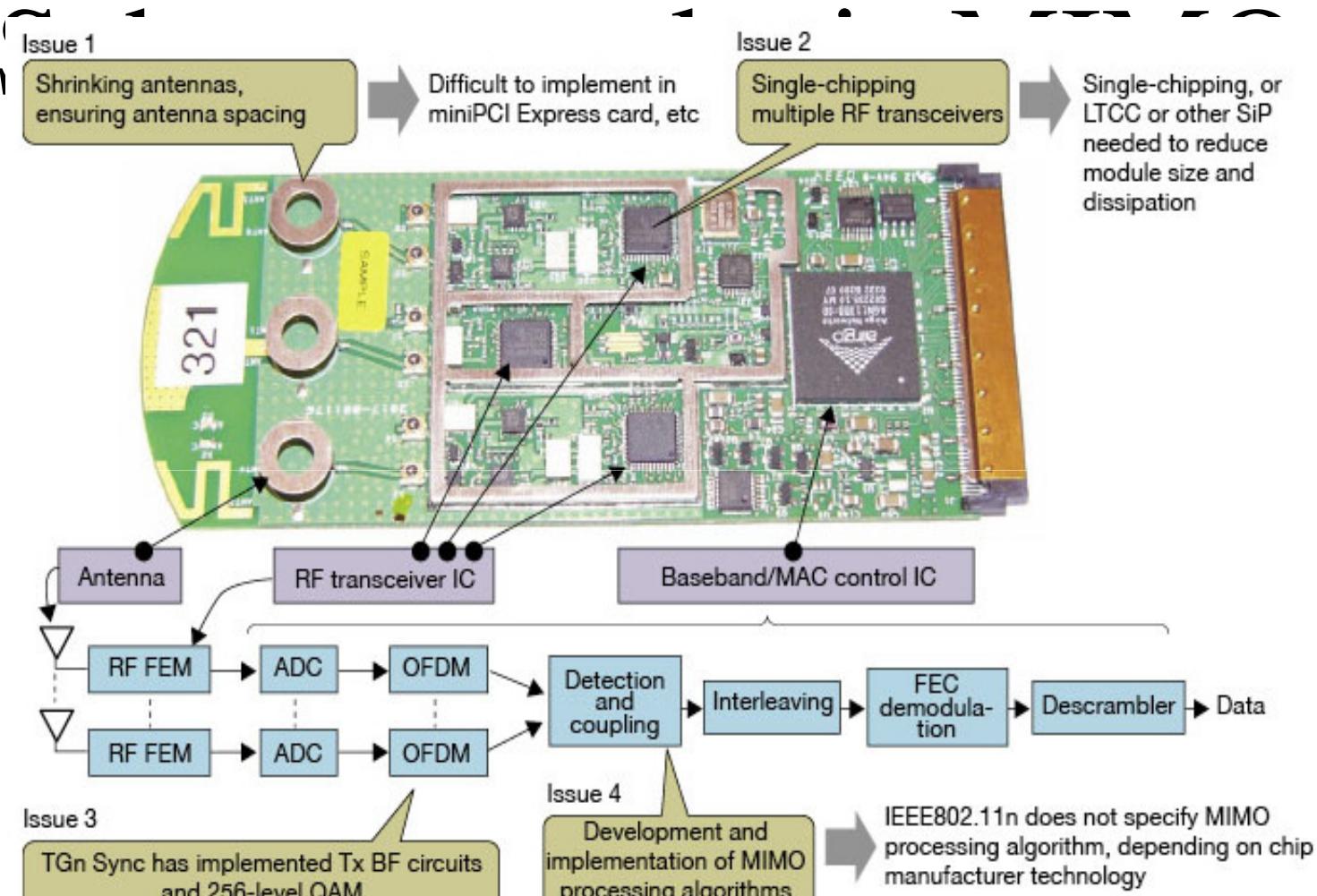
Várias antenas para enviar e várias antenas para receber

Sobre a tecnologia MIMO

- Múltiplas entradas e múltiplas saídas



Várias antenas para enviar e várias antenas para receber

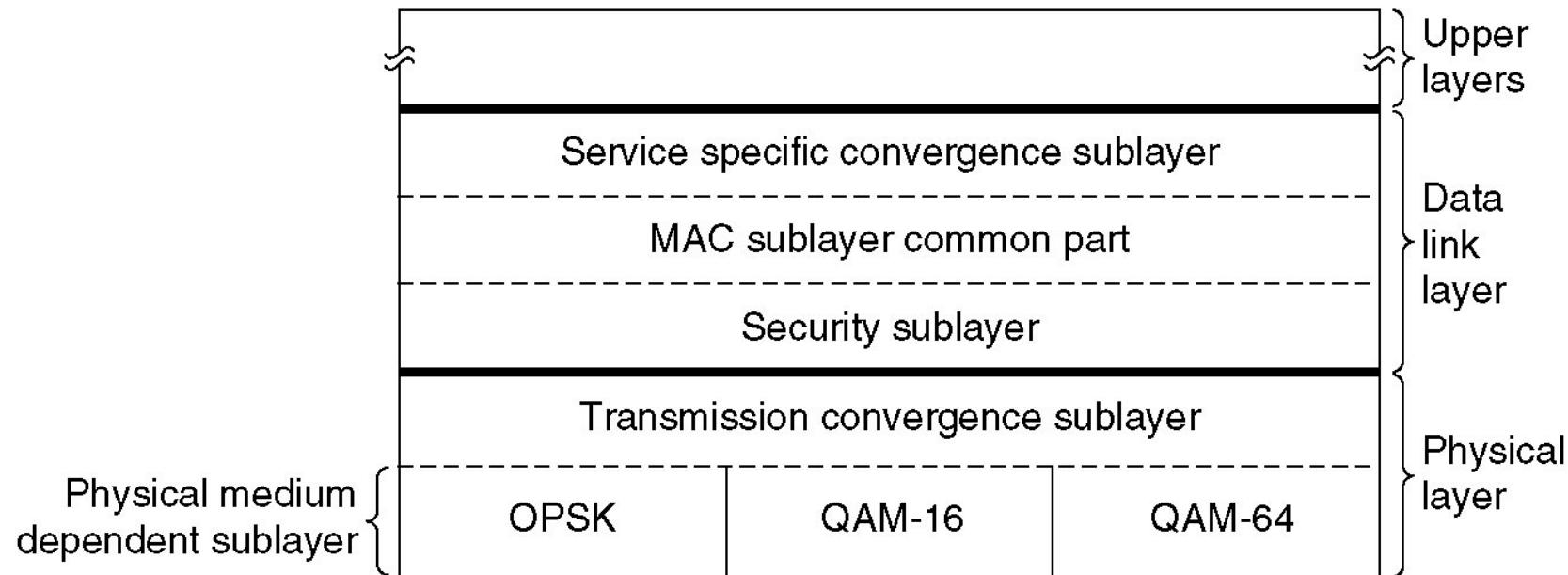


ADC: A-D converter FEC: forward error correction FEM: front-end module
 MAC: media access control MIMO: multiple-input multiple-output OFDM: orthogonal frequency division multiplexing
 SiP: system-in-package

Banda Larga Sem Fio

- Comparação entre 802.11 e 802.16
- A Pilha de Protocolos 802.16
- A Camada Física 802.16
- O Protocolo da Subcamada MAC 802.16
- A Estrutura do Quadro 802.16

A Pilha de Protocolos 802.16

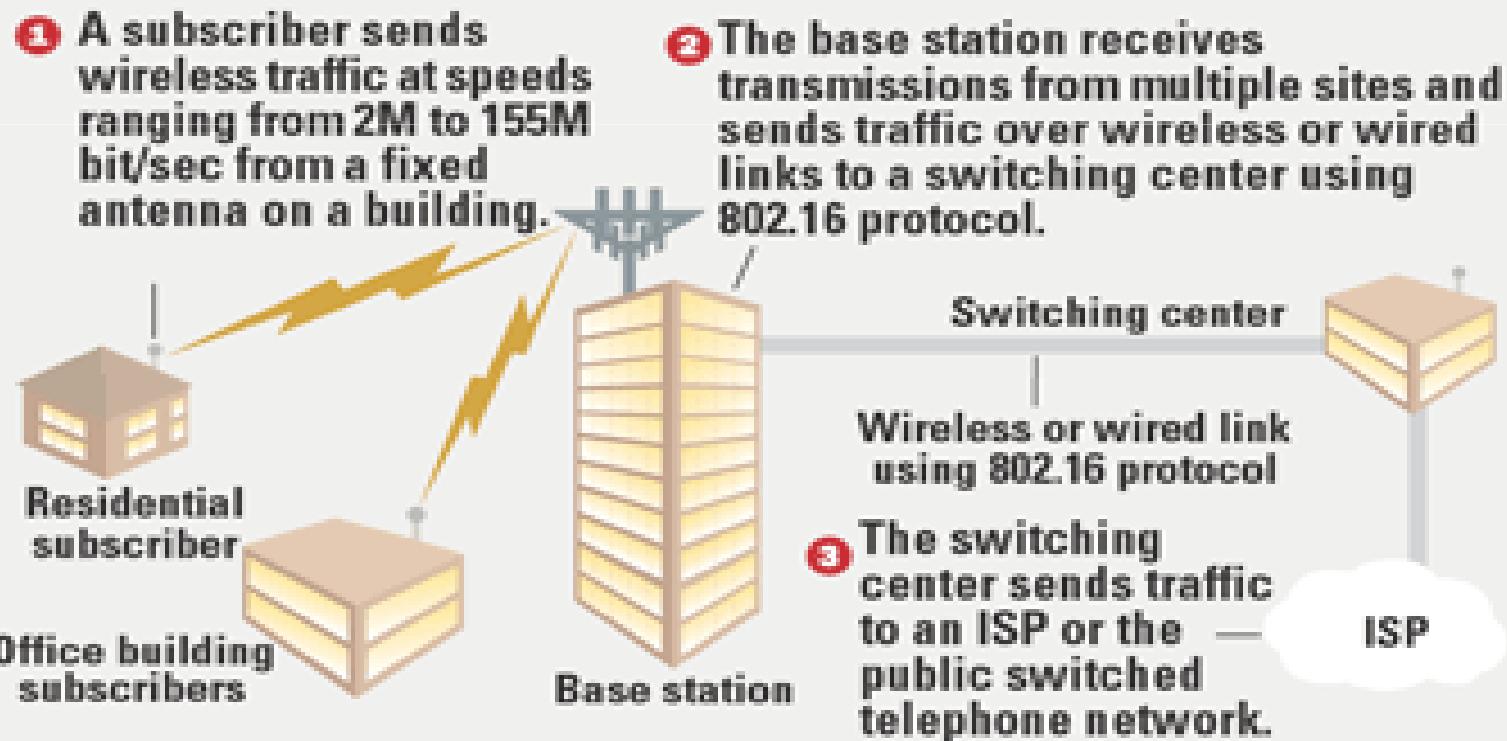


802.16

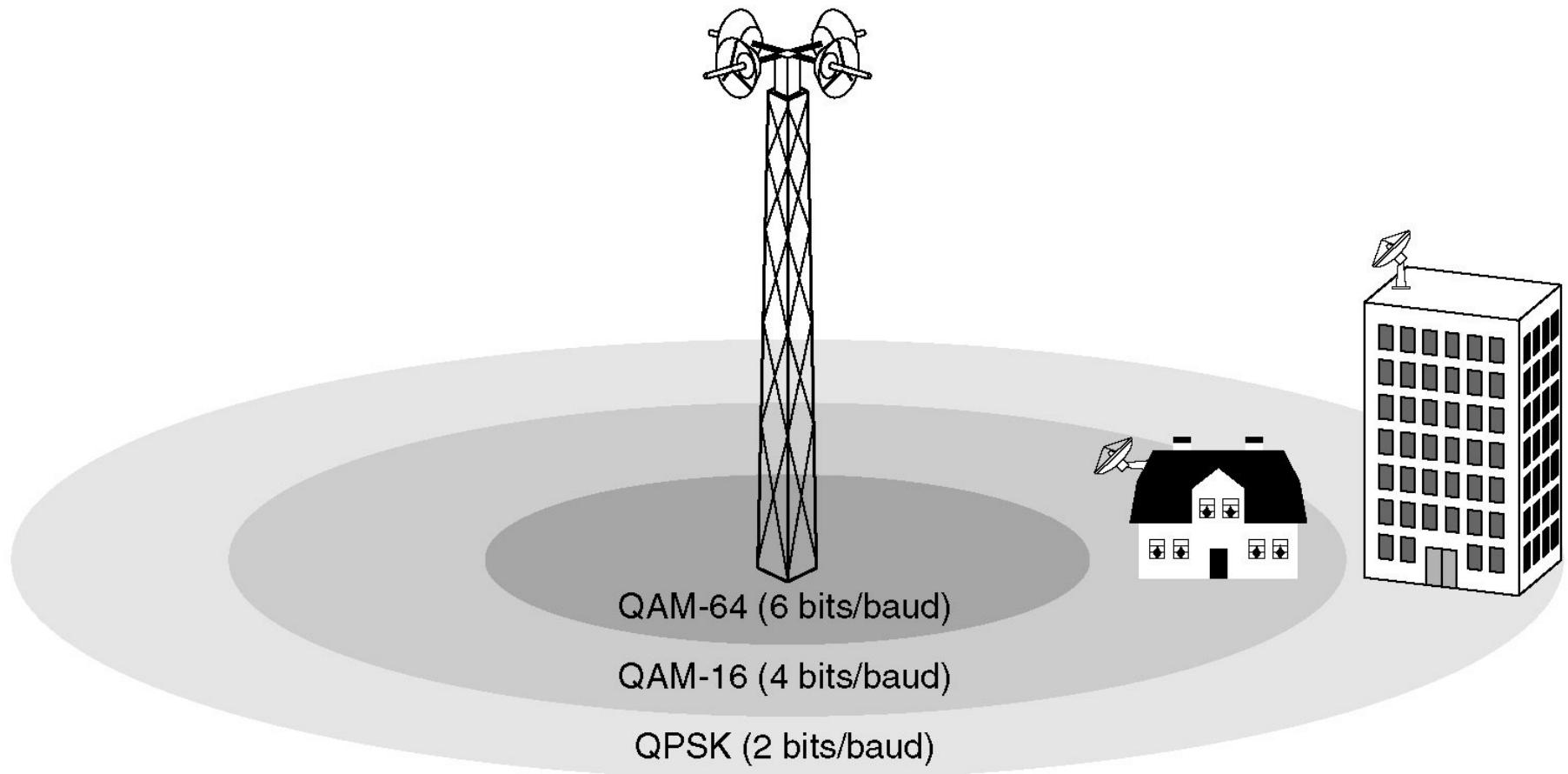
HOW IT WORKS

802.16

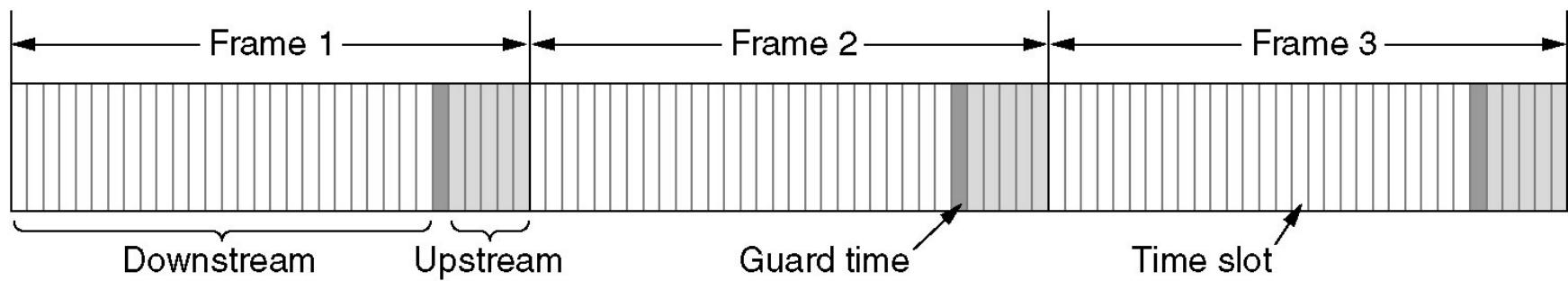
IEEE 802.16 standards define how wireless traffic will move between subscribers and core networks.



A Camada Física 802.16



A Camada Física 802.16 (2)



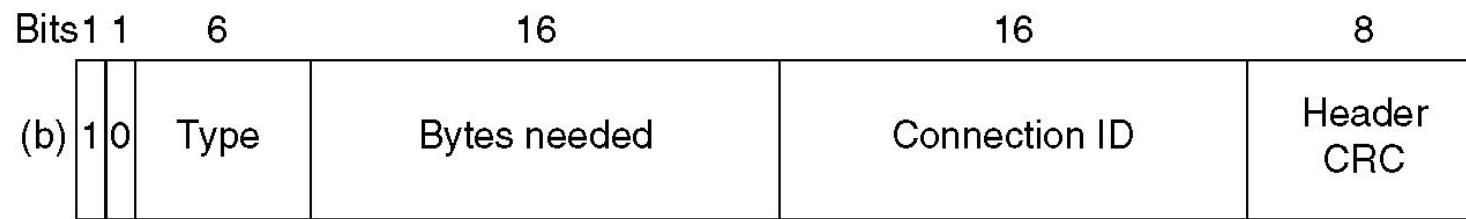
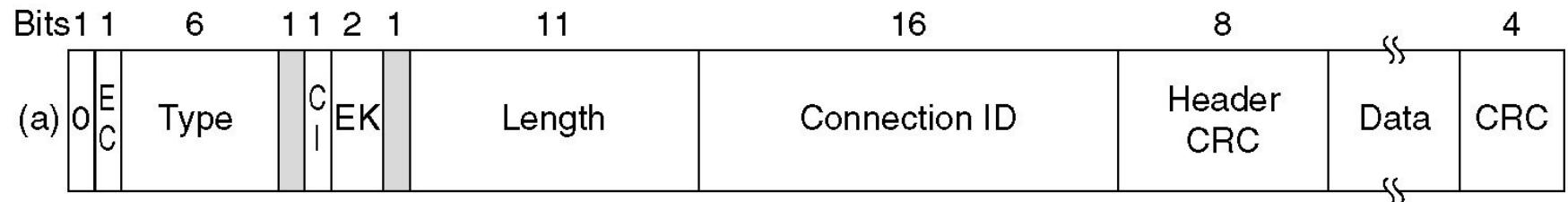
Quadros e slots de tempo para duplexação por divisão de tempo.

O Protocolo da Subcamada MAC 802.16

Classes de Serviço

- Serviço de *bit rate* constante
- Serviço de *bit rate* variável em *real-time*
- Serviço de *bit rate* variável não *real-time*
- Serviço de melhor esforço

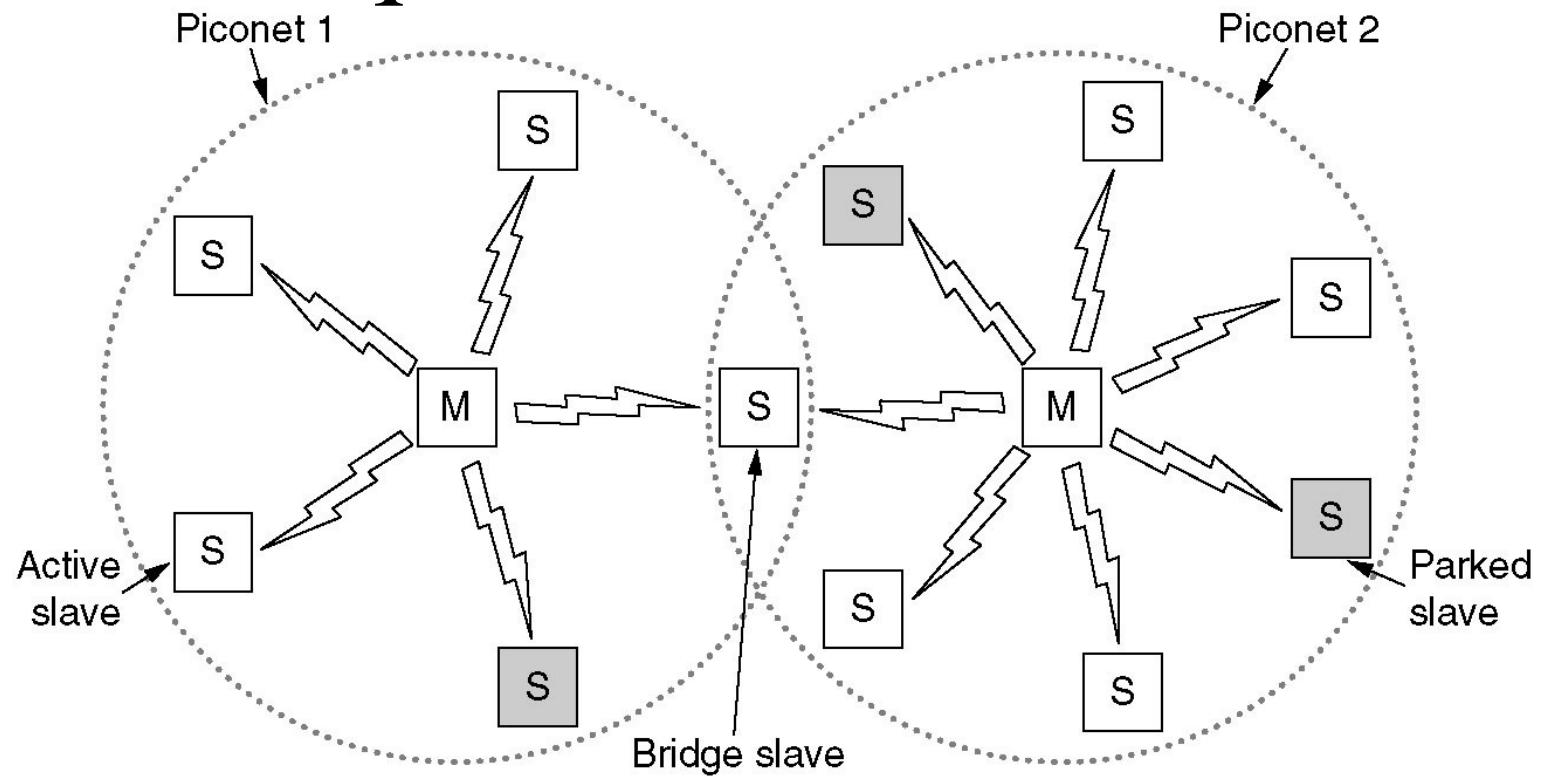
A Estrutura do Quadro 802.16



Bluetooth

- Arquitetura Bluetooth
- Aplicações Bluetooth
- A Pilha de Protocolos Bluetooth
- A Camada de Rádio Bluetooth
- A Camada de Banda Base Bluetooth
- A Camada L2CAP Bluetooth Layer
- A Estrutura do Quadro Bluetooth

Arquitetura Bluetooth



Bluetooth: 802.15

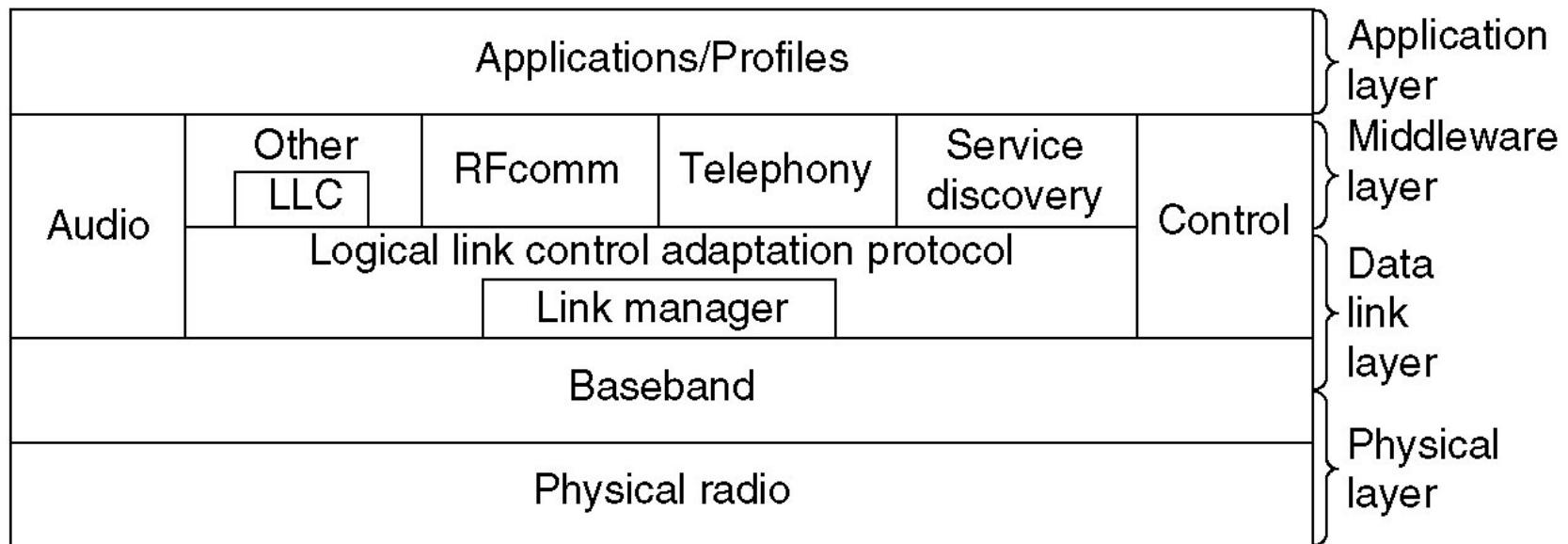
- Used to wirelessly transfer data among devices.
 - Original goal: get ride of the serial cable or USB cable.
 - Upload picture from your cellular phone to desktop PC
 - Wireless headphone...
- Short-range radio frequency (RF) technology
- Operates at 2.4 GHz
 - Interfere with 802.11
- Effective range of Bluetooth devices is 32 feet (10 meters).
- Data at the rate of 1 Mbps
- Compared to 802.11
 - Slow, Low Power, and Short range
 - Master / slave architecture, no collision



Aplicações Bluetooth

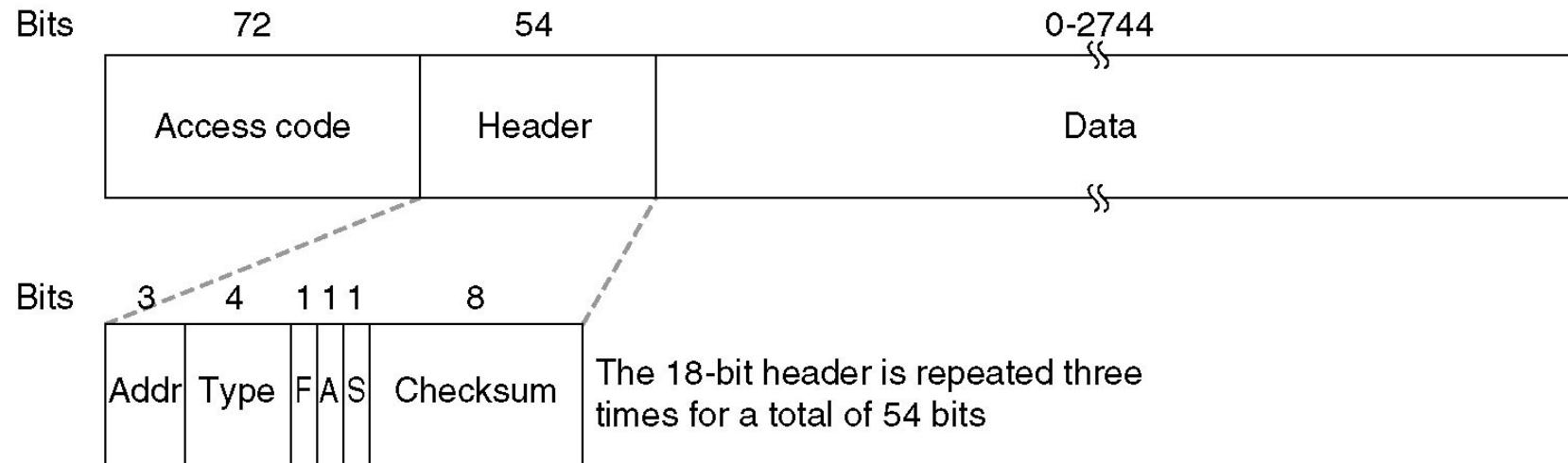
Name	Description
Generic access	Procedures for link management
Service discovery	Protocol for discovering offered services
Serial port	Replacement for a serial port cable
Generic object exchange	Defines client-server relationship for object movement
LAN access	Protocol between a mobile computer and a fixed LAN
Dial-up networking	Allows a notebook computer to call via a mobile phone
Fax	Allows a mobile fax machine to talk to a mobile phone
Cordless telephony	Connects a handset and its local base station
Intercom	Digital walkie-talkie
Headset	Intended for hands-free voice communication
Object push	Provides a way to exchange simple objects
File transfer	Provides a more general file transfer facility
Synchronization	Permits a PDA to synchronize with another computer

A Pilha de Protocolos Bluetooth



- TDM com 79 canais, de 1 MHz e 1 bit/baud (1 Mbps)
- Frequency hopping a 1600 hops/s ou 625 uS (dwell time)
- Normalmente o master usa os slots pares e os slaves os ímpares
- Baseband controla framing e aloca slots para eles.
Normalmente um frame ocupa 1, 3 ou 5 slots
- Settling time pode durar 260 uS (overhead de 260 bits!)
- Range de 10 metros
- Mesma faixa do WiFi, 2.4 GHz - muita interferência

A Estrutura do Quadro Bluetooth



Um típico quadro de dados Bluetooth.

Quanto overhead tem num frame de 1 slot?

UWB (Ultra-wide-band)

- Tecnologia MB-OFDM (Multi-Band Orthogonal Frequency Division Multiplexing);
- Centenas de rajadas de sinais por segundo;
- Menos consumo de energia;
- Largura do canal: 528 MHz, 1,368 GHz e 2,736 GHz;
- Freqüência: 3,1 GHz até 10,6 GHz;
- Modulação: QPSK.

Sumário

Method	Description
FDM	Dedicate a frequency band to each station
WDM	A dynamic FDM scheme for fiber
TDM	Dedicate a time slot to each station
Pure ALOHA	Unsynchronized transmission at any instant
Slotted ALOHA	Random transmission in well-defined time slots
1-persistent CSMA	Standard carrier sense multiple access
Nonpersistent CSMA	Random delay when channel is sensed busy
P-persistent CSMA	CSMA, but with a probability of p of persisting
CSMA/CD	CSMA, but abort on detecting a collision
Bit map	Round robin scheduling using a bit map
Binary countdown	Highest numbered ready station goes next
Tree walk	Reduced contention by selective enabling
MACA, MACAW	Wireless LAN protocols
Ethernet	CSMA/CD with binary exponential backoff
FHSS	Frequency hopping spread spectrum
DSSS	Direct sequence spread spectrum
CSMA/CA	Carrier sense multiple access with collision avoidance

Métodos e sistemas de alocação de canais para um meio comum.

Provinha – 06.10.2009

- Escolhido um canal de transmissão, é ainda possível haver colisões no tráfego de uma célula?
- Um dispositivo móvel nota que o sinal recebido está diminuindo. Pode-se concluir que ele esteja se afastando do AP?
- Compare os campos de um frame 802.3 com um de 802.11. Porque são tão diferentes? Comente 3 diferenças básicas.
- Porque um mecanismo de aviso de recebimento (ACK) é mais importante em wireless do que em ethernet?
- Seria possível utilizar um esquema de cell splitting para melhorar o acesso WiFi em áreas de grande demanda? O que seria preciso fazer?