

Link Layer Services

□ Framing:

- encapsulate bits into frame, adding header
- multiplexing: frame header to identify source, dest
 - example: MAC address
- error detection and correction

□ Flow control:

- pacing between adjacent sending and receiving nodes

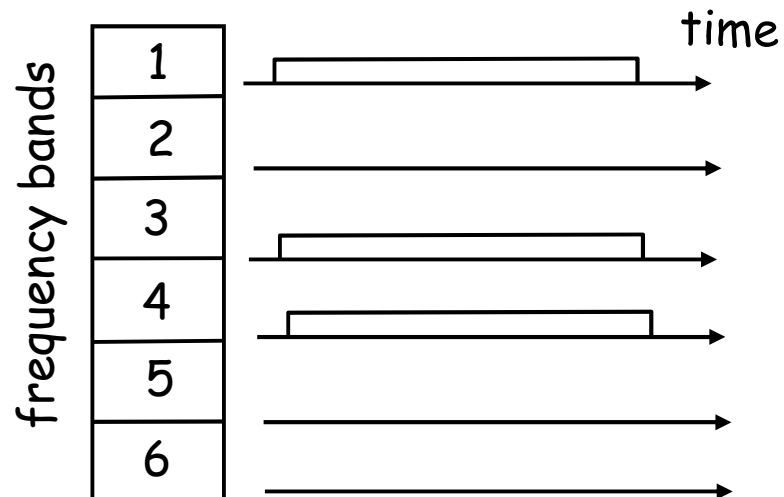
□ Link access (interference and quality of service control)

- media access control (also called multiplexing)

FDMA

FDMA: frequency division multiple access

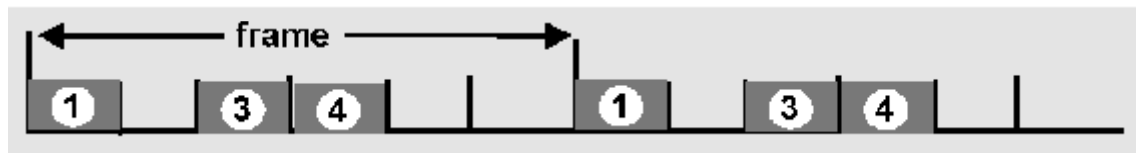
- ❑ Channel divided into frequency bands
- ❑ A transmission uses a frequency band



TDMA

TDMA: time division multiple access

- ❑ Time divides into frames; frame divides into slots
- ❑ A transmission uses a slot in a frame



SDMA

SDMA: space division multiple access

- Transmissions at different locations, if far enough, can transmit simultaneously (same freq.)
 - Example: the cellular technique

1	2	1	2
3	4	3	4
1	2	1	2
3	4	3	4

Suppose 24 MHz spectrum, 30 K per user

$$\text{\#user supported:} = \frac{24\text{MHz}}{30\text{KHz}} = 800$$

$$\text{Using cell \#user supported:} = \frac{6\text{MHz}}{30\text{KHz}} \cdot 16 = 200 \cdot 16 = 3200$$

Q: why not divide into infinite small cells?

CDMA

CDMA (Code Division Multiple Access)

- Unique “code” assigned to each user; i.e., code set partitioning
- All transmissions share the same frequency and time; each transmission uses DSSS, and has its own “chipping” sequence (i.e., code) to encode data
 - e.g. code = -1 1 1 -1 1 -1 1

Examples: Sprint and Verizon, 3G WCDMA and CDMA2000

CDMA: Deal with Multiple-User Interference

- If codes are orthogonal, multiple users can “coexist” and transmit simultaneously with minimal interference

$C_1:$	1	1	1	-1	1	-1	-1	-1
$C_2:$	1	-1	1	1	1	-1	1	1

$C_1 \bullet C_2 =$	1	+(-1)	+ 1	+ (-1)	+1	+ 1	+ (-1)	+(-1)=0

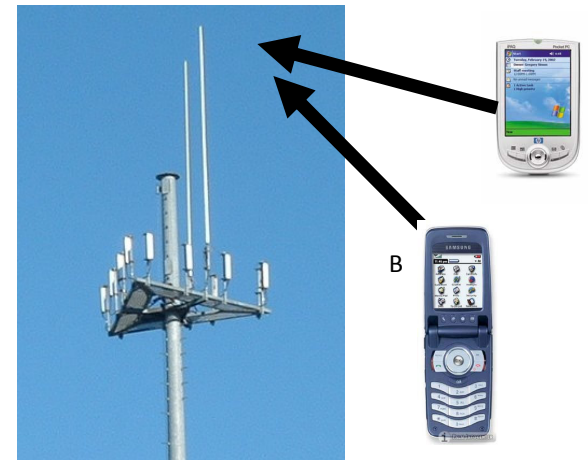
Analogy: Speak in different languages!

Capacity of CDMA

- In realistic setup, cancellation of others' transmission is incomplete
- Assume the received power at base station from all nodes is the same P (how?)
- The power of the transmission with known code is increased to $N P$, where N is chipping expansion factor
- The others remain on the order of P
- Assume a total of M users
- Then

$$SNR = \frac{NP}{(M-1)P + N_0} \approx \frac{N}{M-1}$$

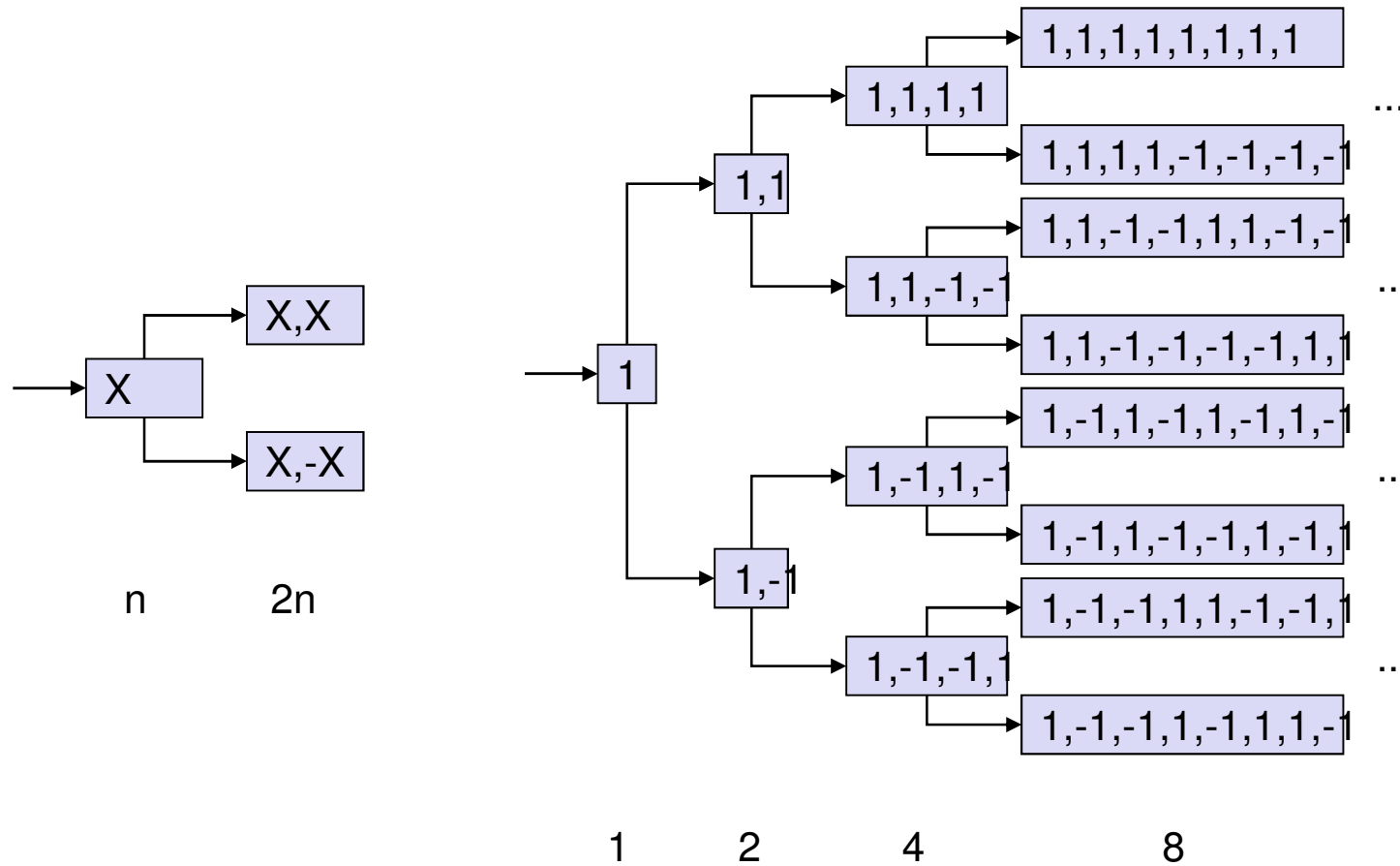
For IS-95 CDMA,
 $N = 1.25M/4800 = 260$



Generating Orthogonal Codes

- The most commonly used orthogonal codes in current CDMA implementation are the Walsh Codes
- Property of Walsh : every row is orthogonal to every other row.

Walsh CDMA Code Assignment



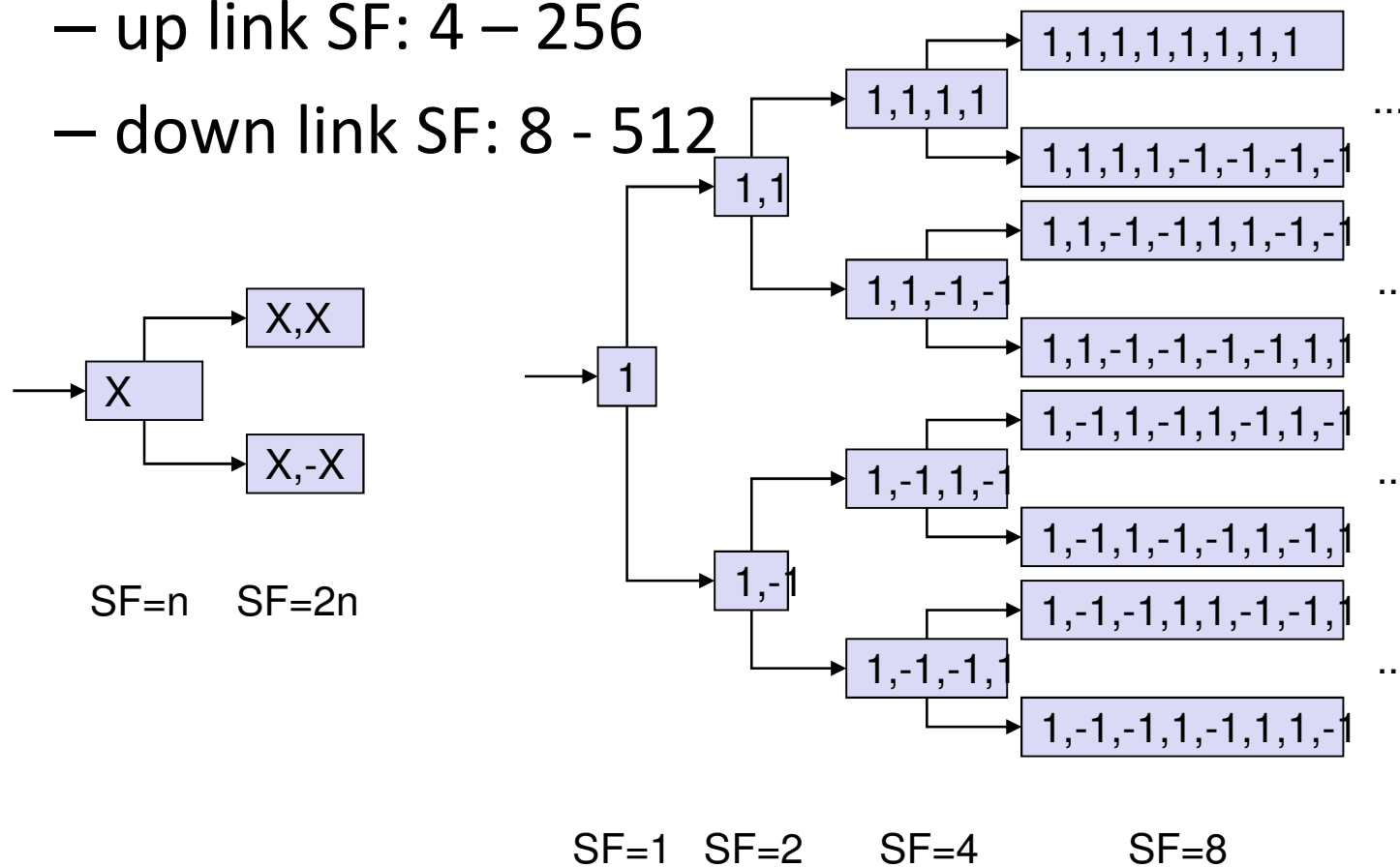
If user 1 is given code $[1, 1, -1, -1]$, what codes can we give to other users?

WCDMA Orthogonal Variable Spreading Factor (OSVF)

- Flexible code (spreading factor) allocation

- up link SF: 4 – 256

- down link SF: 8 - 512



W-CDMA Down Link Capacity

Spreading factor	Channel symbol rate (kbps)	Channel bit rate (kbps)	DPDCH channel bit rate range (kbps)	Max. user data rate with $\frac{1}{2}$ rate coding (approx.)
512	7.5	15	3-6	1-3 kbps
256	15	30	12-24	6-12 kbps
128	30	60	42-51	20-24 kbps
64	60	120	90	45 kbps
32	120	240	210	105 kbps
16	240	480	432	215 kbps
8	480	960	912	456 kbps
4	960	1920	1872	936 kbps
4, with 3 parallel codes	2880	5760	5616	2.3 Mbps

Summary

- SDMA, TDMA, FDMA and CDMA are basic media partitioning techniques
 - divide media into smaller “pieces” (space, time slots, frequencies, codes) for multiple transmissions to share
- Pros and cons of each.
 - FDMA: not flexible for variation in # users and demands; hand off is not smooth.
 - TDMA:
 - CDMA