COMPSCI 314 S1 C

Spread Spectrum Wireless

ATM

Spread Spectrum Wireless

- Develops information theory principle that signals are best protected from noise by making them look like noise
- Instead of allocating a signal to a narrow channel within a radio spectrum, it spreads the signal over the whole spectrum in a predictable way
- Security against snooping
- Security against most forms of noise
- Security against jamming

Two types of spread spectrum

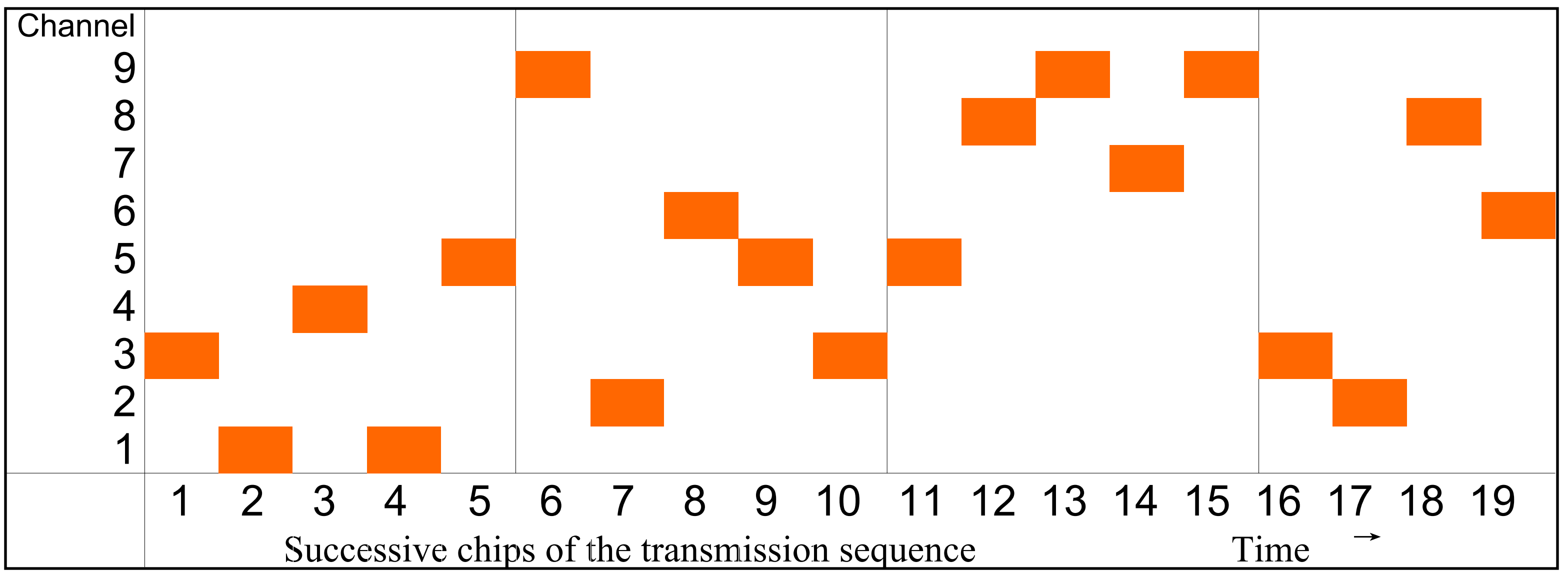
- Frequency hopping spread spectrum
- Direct sequence spread spectrum

Spread Spectrum (2)

- Spread spectrum uses forms of double modulation involving the data, a pseudo-random generator and the RF carrier. The bit-time of the pseudo-random generator is known as a *chip*, and states change at the *chip rate*
- *Frequency hopping* first uses the pseudo-random generator (an *N*-ary generator) to frequency modulate the carrier and then uses data to modulate the (hopping) carrier
- *Direct sequence* first applies the data to the pseudo-random generator (both binary) and then uses the combination to modulate the RF carrier
- 'Slow Spread Spectrum' has the chip rate < data rate, or has several data bits per chip. It is simpler and cheaper but has poorer performance
- 'Fast Spread Spectrum' has the chip rate > data rate, or has several chips per data bit. The equipment is more expensive but gives better noise rejection and security

Frequency Hopping Spread Spectrum

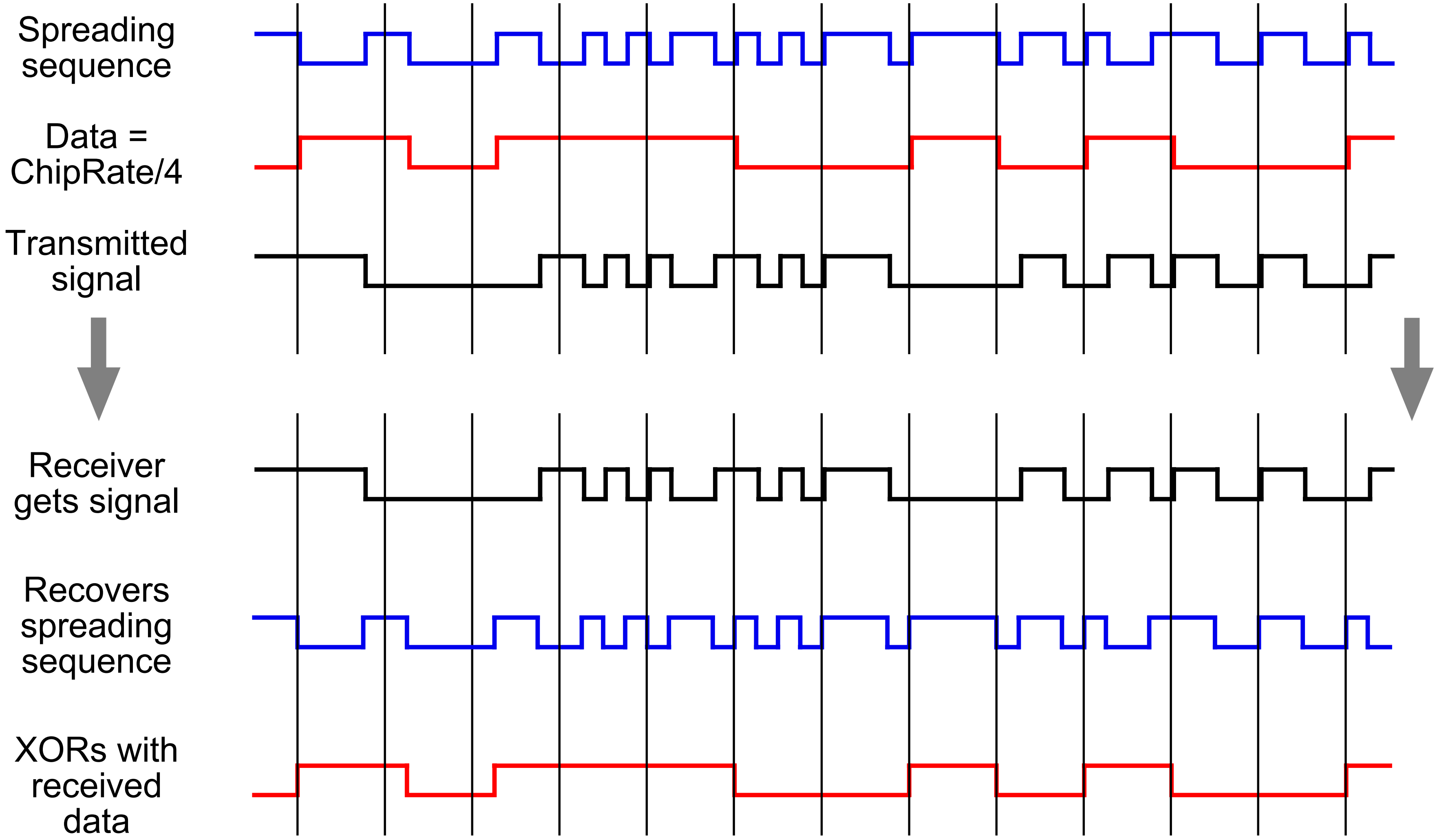
- The spectrum is divided into separate channels (possibly tens or hundreds), usually at a fixed frequency separation
- The transmission frequency hops among the channels according to a pseudo-random sequence and the data is then modulated onto the (hopping) frequency; the receiver tracks the transmitter



Direct-Sequence Spread Spectrum

- In direct-sequence spread spectrum the data is first exclusive-ORed with a pseudo-random binary sequence (the ‘spreading code’).
  This is equivalent to modulating the pseudo-random ‘carrier’ with the data
  - Frequency Shift Keying (FSK)
- The spreading code spreads the radio frequency energy among all of the sidebands, which because of the random code are spread randomly over the available spectrum
- The data modulation appears as a disturbance to the spreading code distribution
- The receiver uses a matching spreading code and detects the difference between what is received and what is expected

Illustration of Direct Sequence Spread Spectrum



Spreading factor

- The number of chips per data bit, N, is known as the spreading factor but is normally called the *processing gain*, written in decibels –

  processing gain (in dB) = $20log_{10}N$
- If noise is concentrated at a single frequency it will interfere with only one channel with frequency hopping; when averaged over all channels used for that bit it will be effectively reduced by a factor N, or by $20log_{10}N$ dB
- A similar averaging process applies to direct-sequence spread spectrum, with each data bit averaged over N chips; with random noise, spreading a data bit over several chips effectively decorrelates the noise with the same overall effect
- The spreading factor or processing gain is effectively a factor by which the signal/noise ratio is improved by using spread spectrum

Multiplexing & Multiple Access Methods

- These all allow different communications to use the same ‘space,’ in a very general sense
- Frequency division multiplexing – different services allocated to different frequencies, such as radio or TV channels
- Time division multiplexing – different services sent at different times, such TV programs (or sequential packets in data communications)
- Space division multiplexing – different services are physically separated, as on different wires or cables, or physically distant radio transmitters on the same frequency
- Code division multiplexing (CDMA) – different spread spectrum services can use the same bandwidth if they use different spreading codes

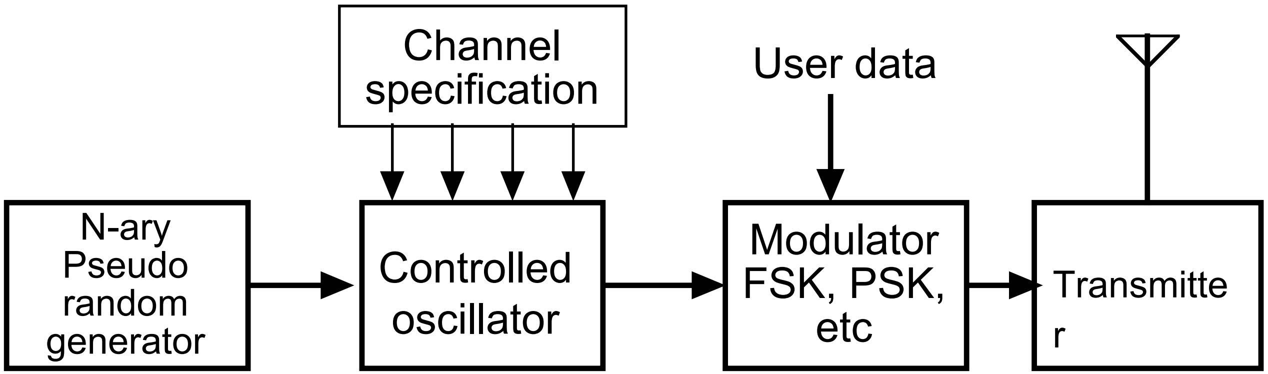
CDMA

(Stands for Code Division Multiple Access)

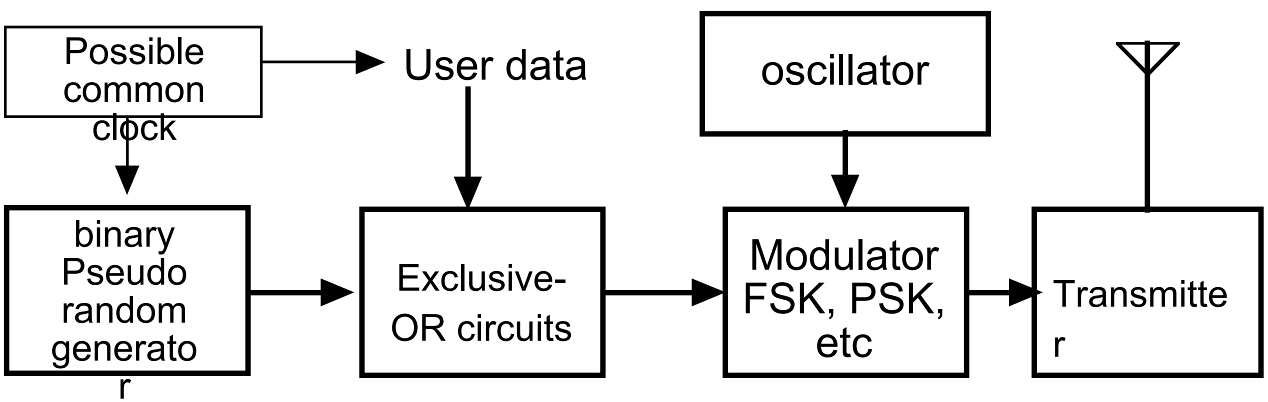
- With slow spread-spectrum, collisions appear as bursts of noise, perhaps affecting a few bits
- With fast spread-spectrum a collision affects only part of a bit. Interfering stations just provide a background noise level which increases with more stations
- Direct-Sequence spread-spectrum suffers from a form of capture effect in which strong local transmitters overwhelm a weaker signal. The weaker signal is not just there as interfering background – beyond a certain difference in strength it just disappears!

  (A similar effect occurs with FM transmission, given a good receiver!)

Spread Spectrum Transmitters

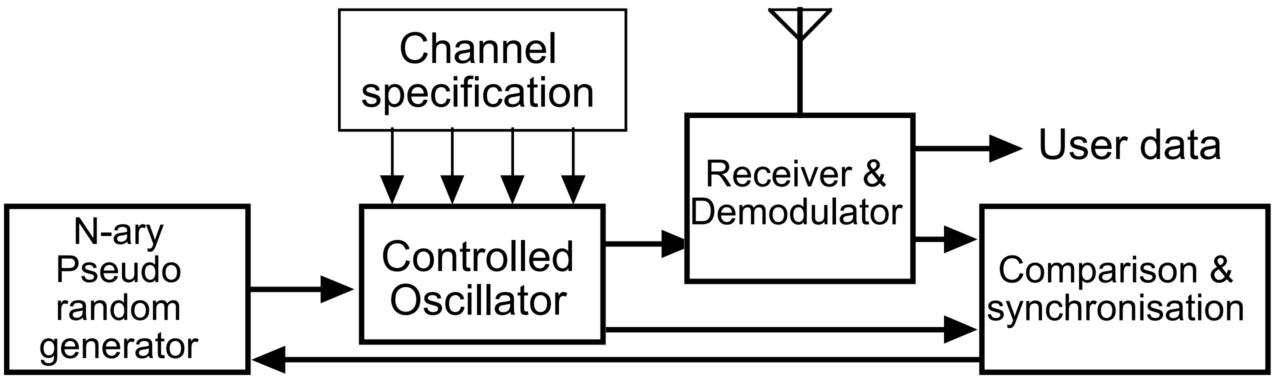


Frequency Hopping Spread Spectrum

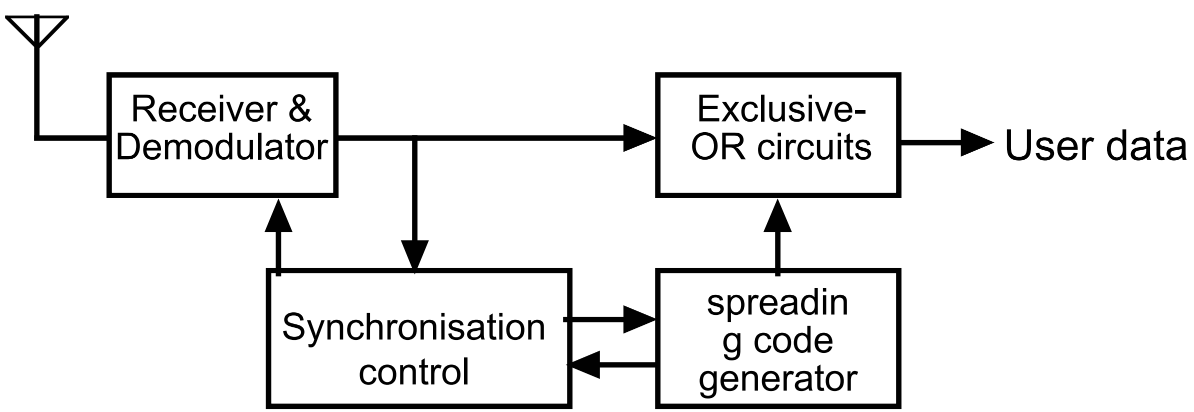


Direct Sequence Spread Spectrum

Spread Spectrum Receivers



Frequency Hopping Spread Spectrum



Direct Sequence Spread Spectrum

Comments on Spread Spectrum

Receivers always work by hunting for a received sequence with the correct hopping or spreading code. They normally rely on very accurate time synchronisation between the receiver

It's also possible to synchronise of a direct-sequence receiver using a known preamble to each transmitted message

A frequency hopping receiver might start with the 'time of day' a little earlier than expected and run the hopping clock slightly fast. Eventually the received and expected hops will match and the clocks can synchronise

802.11b wireless uses direct sequence spread spectrum, (DSSS) in the 2.4 GHz ISM band

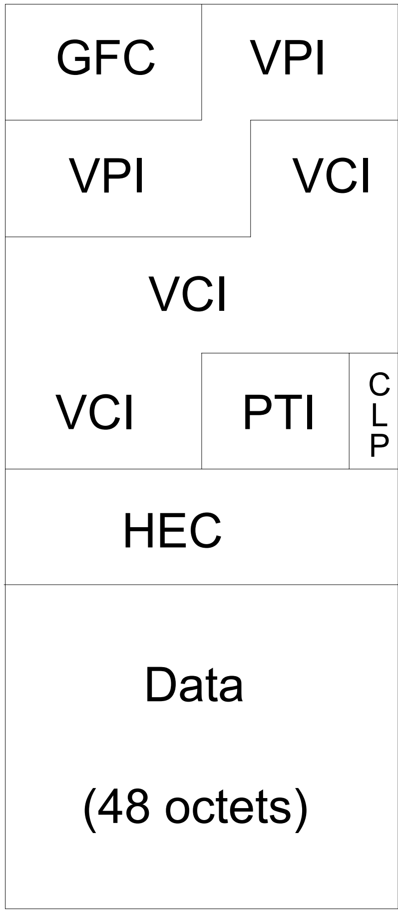
ATM: Asynchronous Transfer Mode

- ‘Ordinary’ message formats are inefficient or difficult to handle because –
- It may be difficult to decide on length (count, delimiters, etc)
- Checksumming all messages at all levels is expensive
- Small urgent messages may be delayed behind large unimportant ones
- Header and message delimiters waste space

Therefore …

use small packets of constant size and minimum overhead (no delimiters or counts and minimal checksum)

ATM cell format



GFC = Generic Flow Control	(4 bits)
VPI = Virtual Path Identifier	(8 bits)
VCI = Virtual Channel Identifier	(16 bits)
PTI = Payload Type Indicator	(3 bits)
CLP = Cell Loss Priority	(1 bit)
HEC = Header Error Control	(8 bits)
	(40 b = 8B header)

Data or Payload
Always fixed at 48 octets

Cell fields

- GFC Generic Flow Control – allows user to specify flow control
- VPI Virtual Path Identifier – part of the Virtual Circuit Identifier. Allows several VCIs to be ‘bundled’ together and routed as a unit
- VCI Virtual Channel Identifier – part of Virtual Circuit Identifier
- PTI Payload Type – 4 system functions and 4 user functions.
- CLP Cell Loss Priority – marks cell for preferential discard in event of congestion
- HEC Header Error Control – CRC checksum over 5 header octets, using polynomial $x8 + x2 + x + 1$, gives error detection and some error correction

- Payload Always 48 octets

User PTI (Payload Type Indicator)

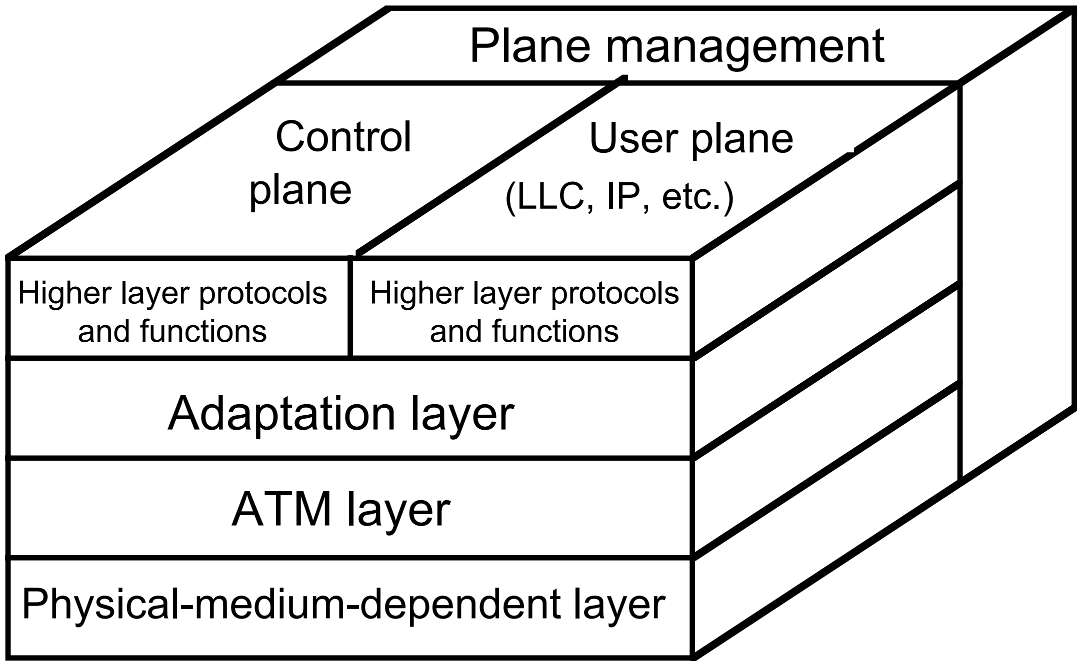
Three bits: 0 *x* *y*

- first bit is always 0 (signifies user)
- *x*, initially 0, set to 1 if congestion is encountered
- *y* available for user indication

- ATM provides Virtual Circuits. The type of connection is negotiated at call establishment and the AAL (Adaptation Layer – see later) and other attributes are associated with the Virtual Circuit
- ATM is meant to provide all types of service – computer data, time-critical voice and video, constant and variable bit rate …

ATM Layering

- ATM can be a full Virtual Circuit-based network provider
- It often looks like a Physical/MAC layer, providing transport for IP etc.



B-ISDN asynchronous transfer mode (ATM) protocol model

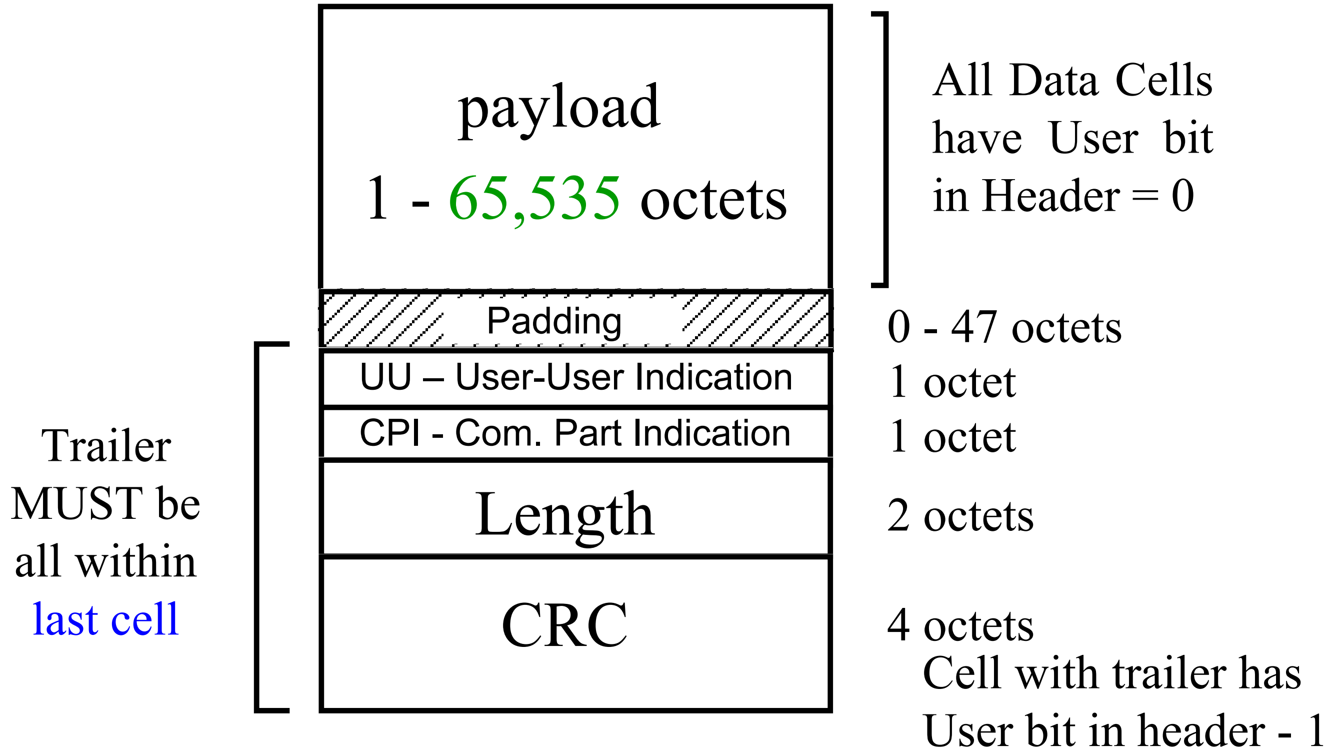
ATM Adaptation Layers

These provide combinations of constant or variable bit rate and connection or connectionless operation. Most are complex; we just look at AAL5.

AAL type	Bit rate	Connection mode	Other features	Uses
1	constant (CBR)	Connection oriented	Segmentation, cell loss & misdelivery, time-critical	fixed bit rate simulation
2	variable (VBR)	Connection oriented	Segmentation, cell loss & misdelivery, time-critical	Video and audio
3	variable (VBR)	Connection oriented	Bursty data services	Computer data transfer
4	variable (VBR)	Connectionless	Bursty data services	Computer data transfer
5	variable (VBR)	either	'best effort,' detection but not recovery	Computer data transfer

AAL5 (ATM Adaptation Layer 5)

AAL5 provides a simple data transfer, with no multiplexing and minimum overhead.



AAL 5 Sublayer

AAL5 (2)

- Data, up to 65,535 octets, is split into 48-octet cell payloads and each cell is sent with no other identification apart from its VPI/VCI.
- All first cells have a user indication bit = 0 in the header.
- The final cell has a user indication bit = 1 and 8 octets aligned at the end of the cell.
  - 2 octets available for system and user communication
  - 2 octets of count of the valid data octets
  - 4 octets of CRC, similar to IEEE 802.3
- The final cell may contain padding, between the end of the data and the trailer. The padding length is computed from the number of cells and the length octet, allowing for the 8 octet trailer