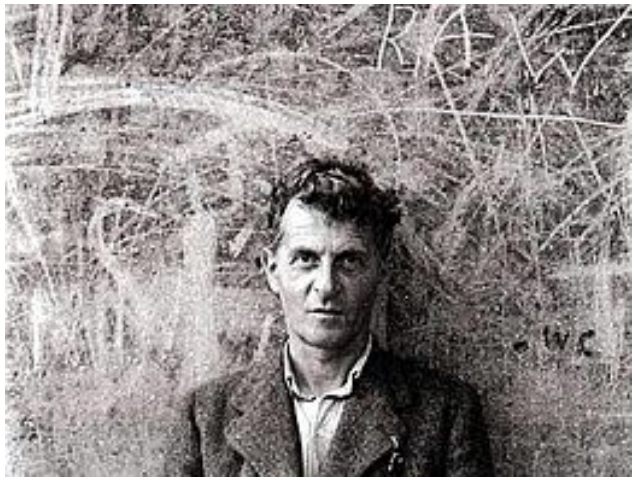
Crash Course in Wireless Video

Dr. Eren Soyak

Lifemote

April 24, 2018

Ludwig Wittgenstein

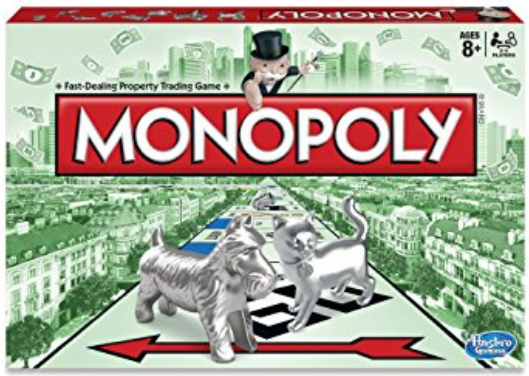


- The *context* in which words are used, the intent with which they are uttered, determines their meaning.
- Successful communication is guessing which game the speaker is playing.
- What game would a lion be playing?

```
if a lion could speak, we could not understand him
```

```
‘‘you never help around the house’’
```

```
(REASSURE ME)
```

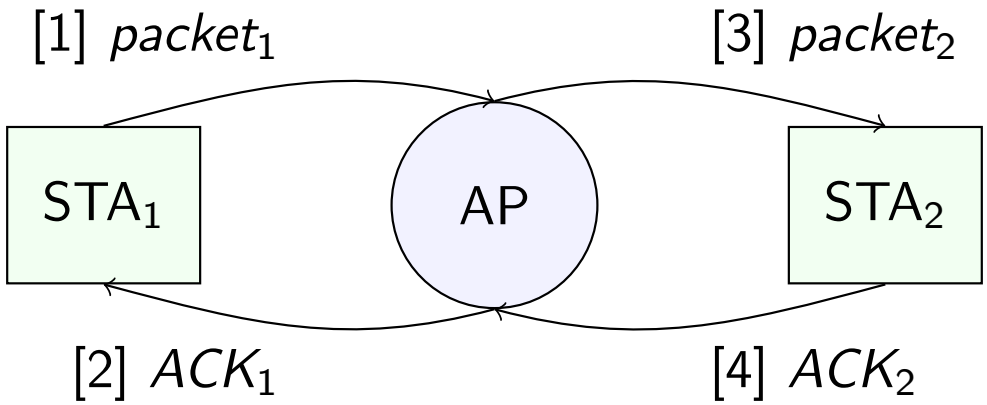


Workshop Overview

- The intent is to demystify WiFi and video
- Our goals are to get an idea about:
  - How 802.11 works
  - How WiFi might fail
  - How video compression works
  - How video over WiFi might fail

What is WiFi?

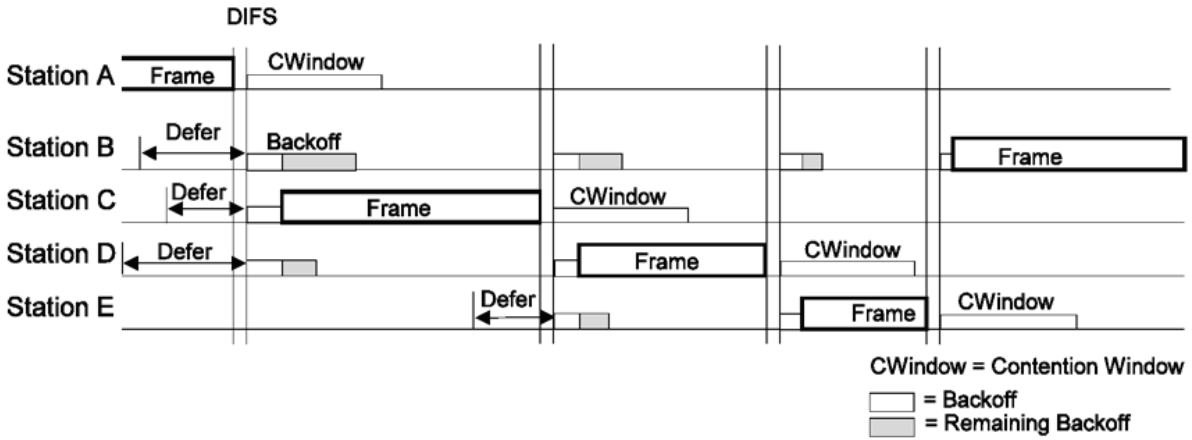
- MAC-level communication between AP-STA or STA-AP-STA



- MAC addresses, no IP info (LAN-only)

CSMA

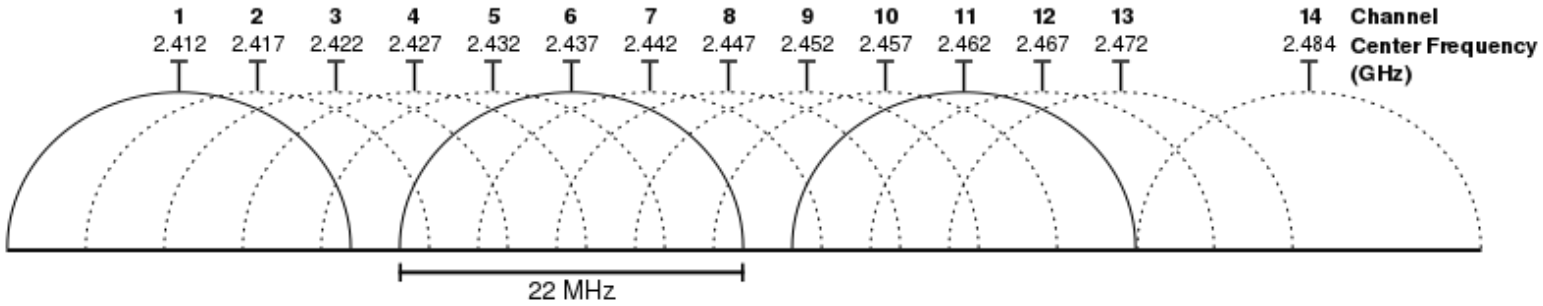
- WiFi devices wait for the channel to be free, back off a random amount of time, and then transmit if the channel is still free



- Video transmitters back off less than regular data

Channels

- WiFi uses OFDM subcarriers across *channels*
- 2.4 GHz channels overlap

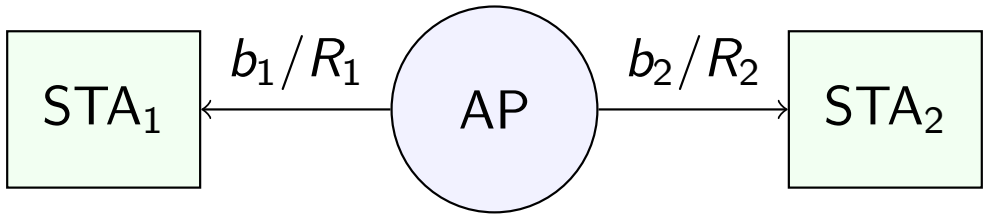


- 5 GHz channels don't overlap

[https://en.wikipedia.org/wiki/List_of_WLAN_channels, available Apr. 10 2018.]

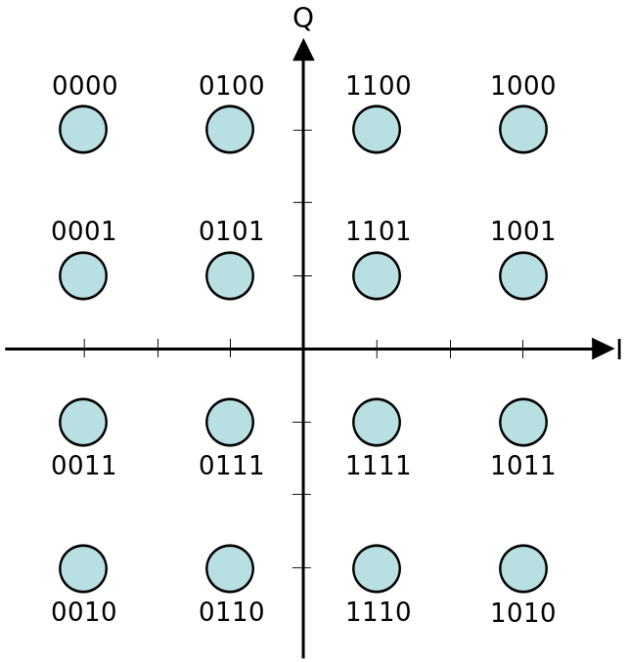
Airtime

- STA_1 takes $\frac{b_1}{R_1}$ sec
- STA_2 takes $\frac{b_2}{R_2}$ sec
- If in total client devices exceed 100% of time, they share *time* (not *rate*) equally



MCS

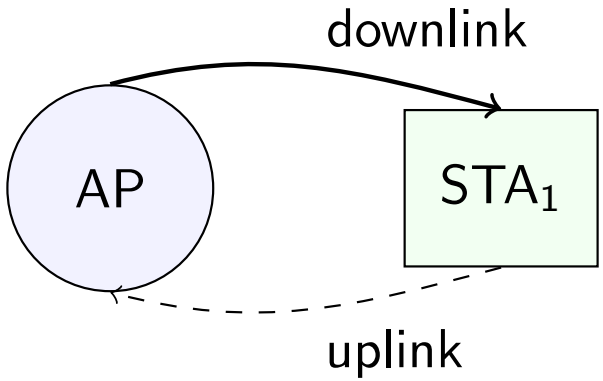
- **M**odulation **S**Coding **S**cheme
- Modulation: BPSK, QPSK, QAM



- Coding: Error control bits (redundancy 2/3, 3/4, 5/6).

RSSI

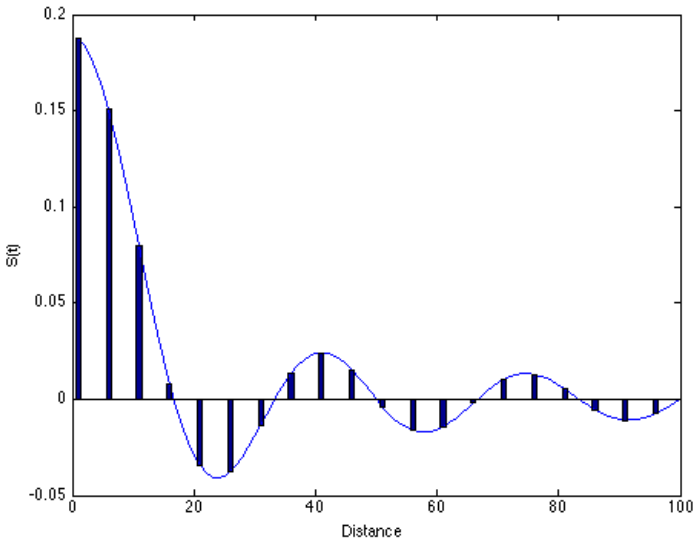
- **R**eceived **S**ignal **S**trength **I**ndication



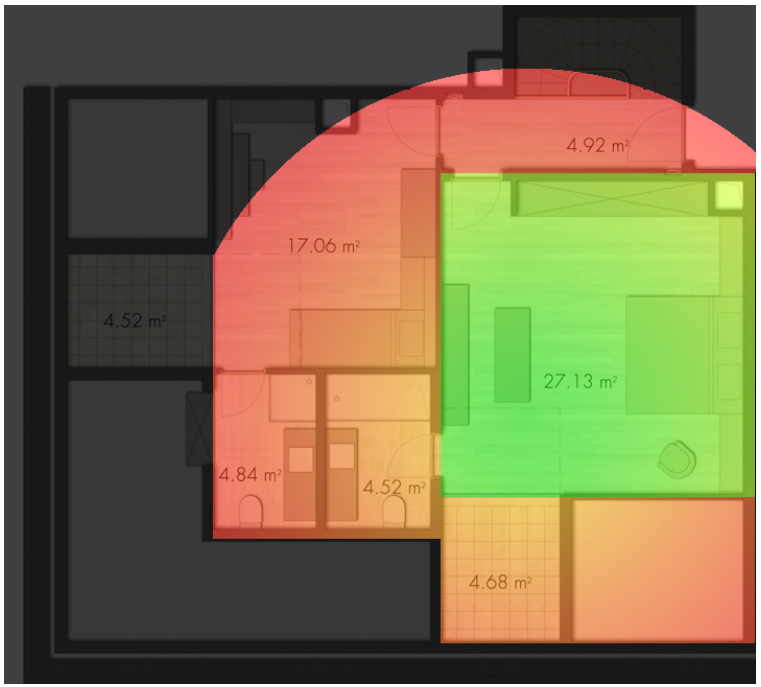
- PHY Rate iteratively controlled, but usually closely correlated to RSSI
- Uplink usually weaker, may be *very* weak with TX Beamforming

Attenuation

- Attenuation can come about due to two reasons:
  - Distance (logarithmic)
  - Interposing objects (air, walls, etc.)



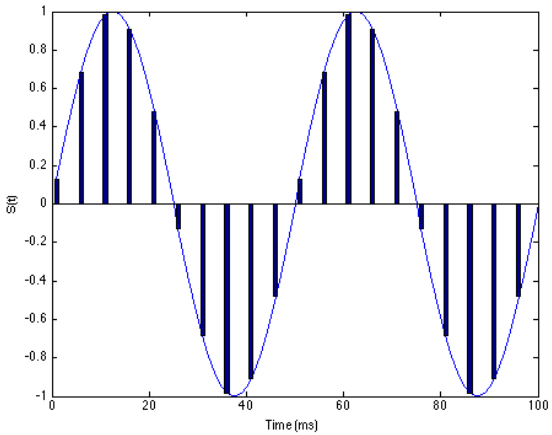
Signal attenuating over distance



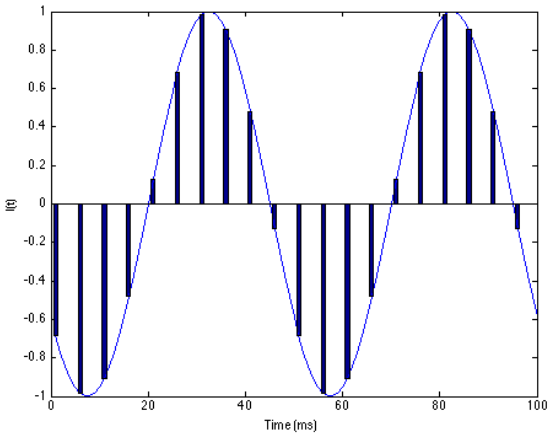
Sample WiFi signal strength

Interference

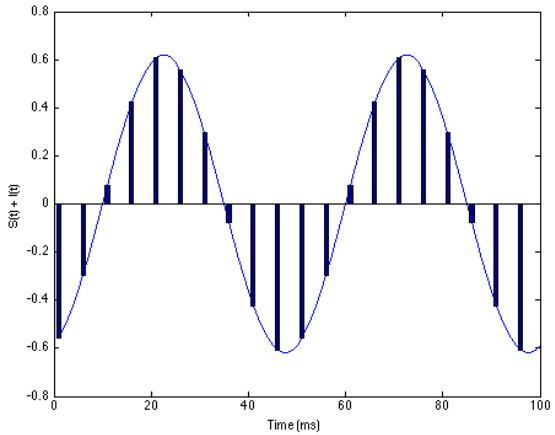
- Interference can come about due to various reasons
  - WiFi on overlapping channels (2.4 G)
  - Other devices (Bluetooth, Zigbee/Zwave, Baby monitors, Microwaves, DECT phones)
  - The signal interfering with itself due to *multipath*



Original Signal



Interfering Signal

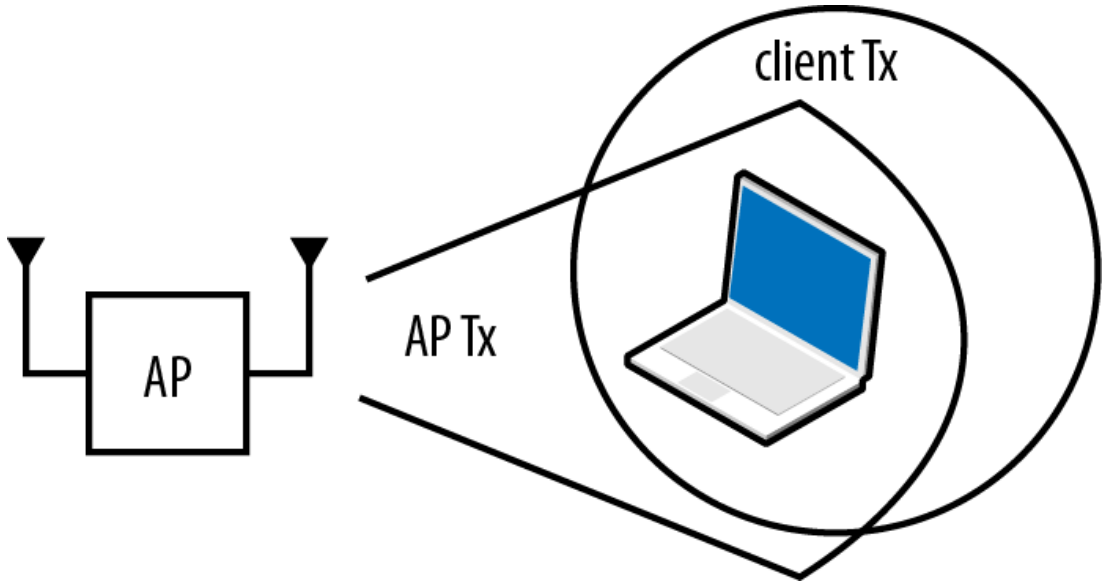


Interfered Result

- Interference feature not bug when used for Beamforming ☺

MIMO and Beamforming

- MIMO: multiple spatial streams (when RSSI good)
- STBC: single spatial stream over multiple transmitters (when RSSI poor)
- Beamforming: phase shift transmitters for maximum constructive interference at receiver



[www.safaribooksonline.com/library/view/80211n-a-survival/9781449335472/ch04.html, available Apr. 10 2018.]

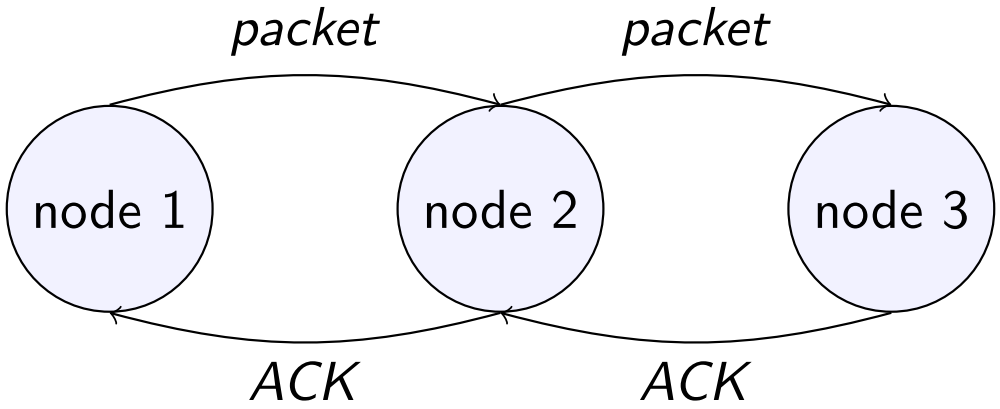
Hidden Nodes and Collisions

- When two transmitters can't hear each other, but their intended receivers can hear both, the packets will **collide**

- Power reduction, channel change or RTS/CTS

Layer 2 vs Layer 4 Rate

- TCP rate (rate user sees) is roughly 1/2 PHY rate *on an empty channel*
- TCP flow control meant to shelter intermediate network nodes from queue overflows



- Node 1 won't send another packet until it receives an ACK from Node 2

802.11g

- Finalized 2003
- 54 Mbps (64-QAM, 20 MHz)
- 2.4GHz, 20 MHz

802.11n

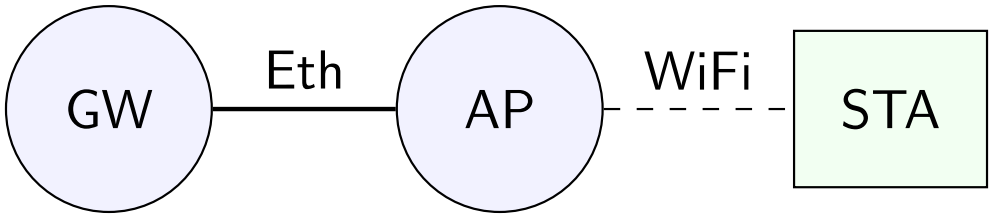
- Finalized 2009
- 150 Mbps per chain (64-QAM, 40 MHz)
- 65 Mbps per chain at 20 MHz
- Aggregation
- Up to 4x4 MIMO
- 2.4GHz / 40 MHz, 5 GHz / 40 MHz
- Non-standard beamforming

802.11ac

- Finalized 2013
- 433 Mbps per chain (256-QAM, 80 MHz)
- More aggregation
- Up to 8x8 MIMO
- No 2.4 GHz, 5 GHz / 80 MHz (160 MHz Wave 2)
- Standard beamforming

AP Behind GW

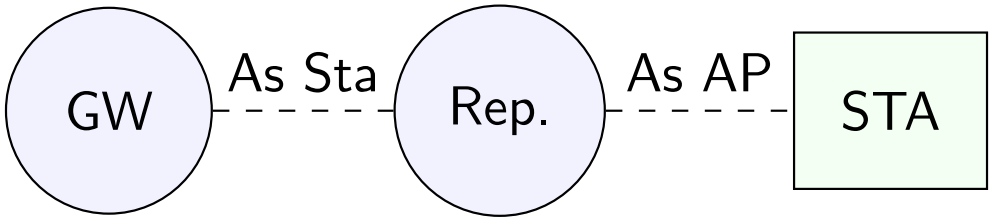
- GW provides IP's, routing
- AP connected via Ethernet, only provides WiFi access



- GW WiFi should be off: WiFi AP's within 1m of each other can blind each other even when not on same channel

Repeater

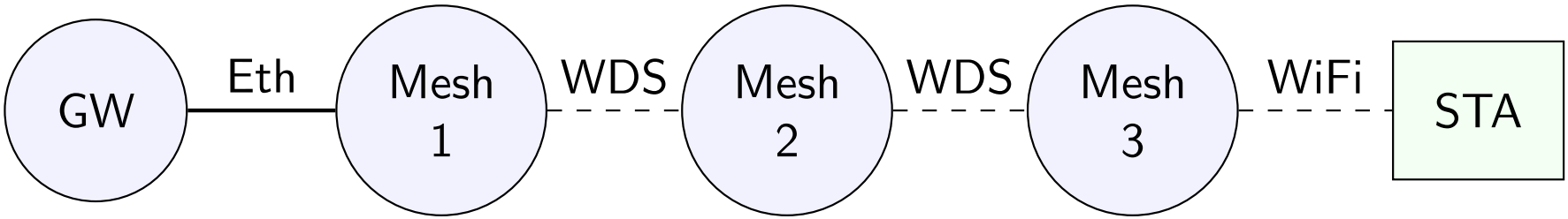
- Repeater connected via WiFi to GW



- If repeater too close to GW, introducing needless overhead hop
- If repeater too far from GW, that link will bottleneck all clients connected to repeater
- A DBC repeater set to repeat 2G SSID of GW is handicapped

Mesh

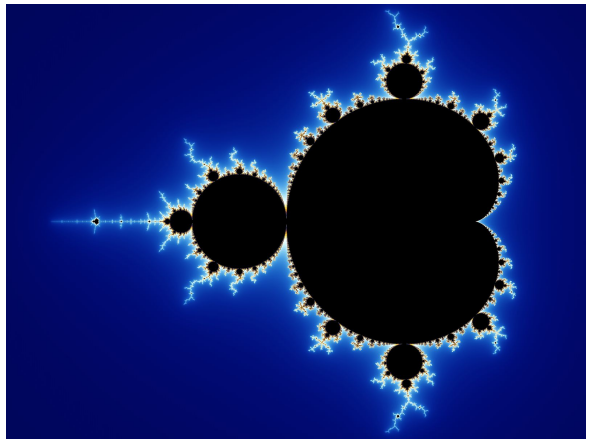
- First Mesh point connected to GW via Ethernet
- Mesh points use WDS among each other (four address space link)



- If WiFi of GW is left on, not only might it blind nearest Mesh point, but it will handicap Steering

Fractals

- Fractals are phenomena that display a repeating pattern at every scale, known as *expanding* or *evolving symmetry*.
- These forms are frequently encountered in nature and engineering.

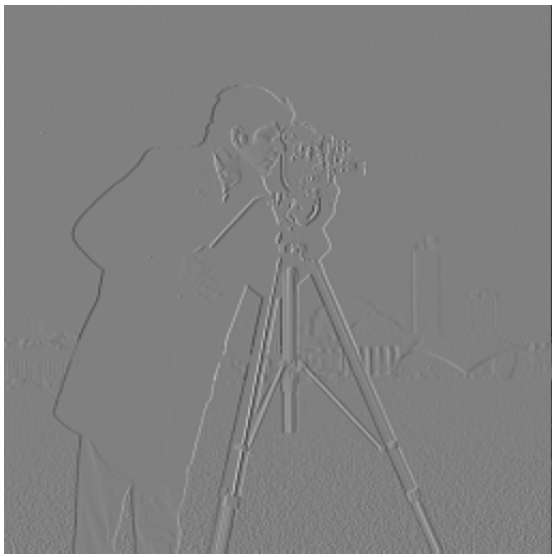


[https://en.wikipedia.org/wiki/Fractal, available online Nov. 16 2016.]

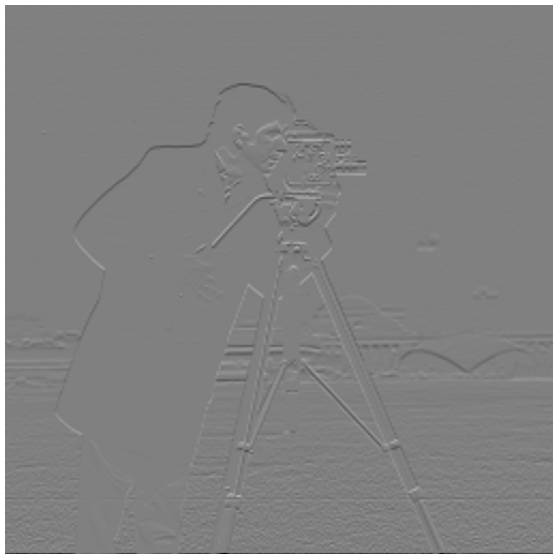
Image Compression

- Image *compression* aims to reduce the amount of space needed to store a digital image.
- This is commonly done by exploiting the *spatial redundancy*.
- *Intra Prediction* does this by using similarity between neighboring pixels

Cameraman



Horizontal Gradient



Vertical Gradient

Block Coding

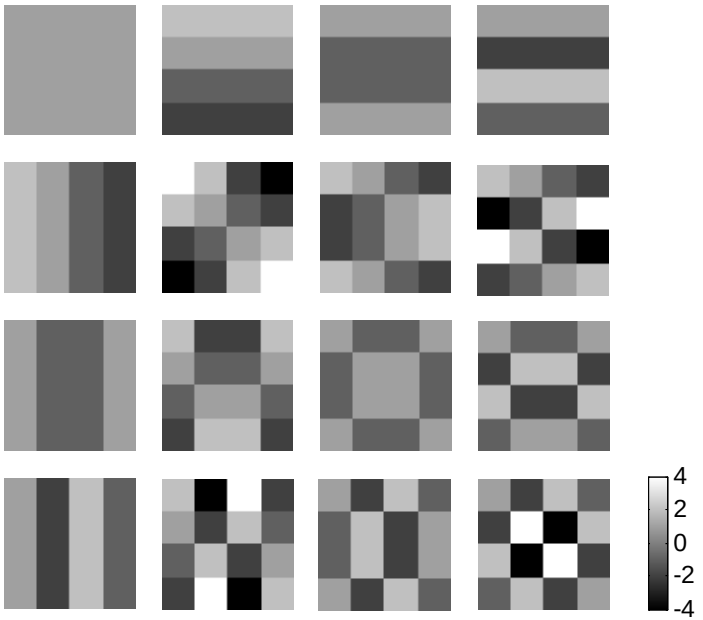
- *Block coding* divides the image into blocks and
  1. *transforms* the pixels in each block, producing *transform coefficients*
  2. *quantizes* each coefficient
  3. writes transforms to a *bitstream* via *entropy coding*

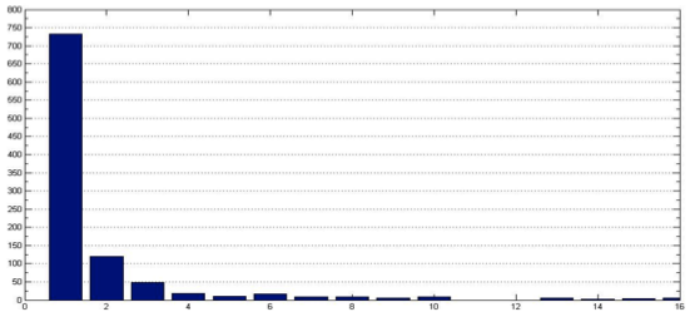
$$I_{x,y} \rightarrow \boxed{\text{transform}} \rightarrow C_i \rightarrow \boxed{\text{quantization}} \rightarrow \hat{C}_i \rightarrow \boxed{\text{entropy}} \rightarrow \text{bits}$$

Transform Coding

- *Transform coding* converts pixel intensities to *transform coefficients*.
- The *basis functions* of the transform are multiplied with the intensity matrix to get each coefficient value:

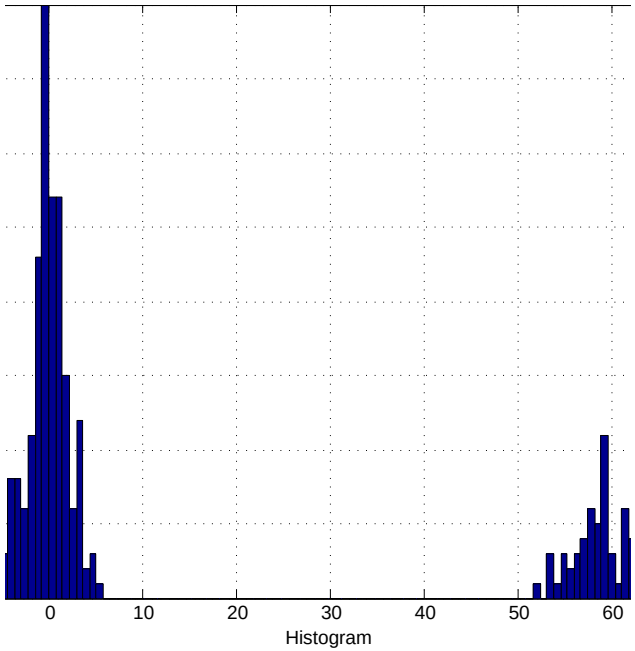
$$\begin{vmatrix} 100 & 101 & 102 & 99 \\ 102 & 101 & 11 & 10 \\ 104 & 102 & 11 & 11 \\ 103 & 104 & 11 & 13 \end{vmatrix}$$





Quantization

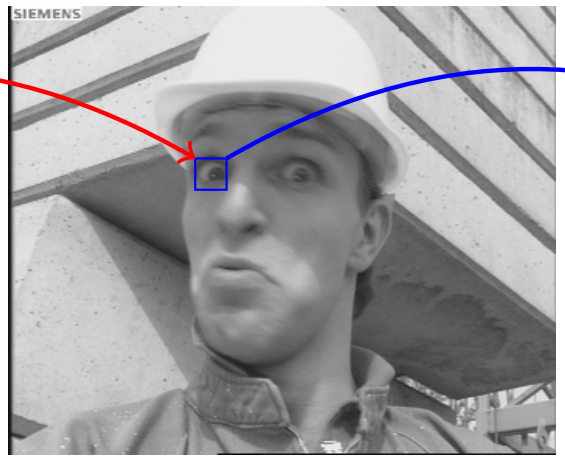
- The goal of quantization is to reduce the dynamic range of transform coefficients.
- Where the transform is reversible, **quantization is the only source of distortion**.
- Using a larger quantizer (i.e., dividing by a larger number) is called *coarse* quantization, and using a small quantizer *fine* quantization.



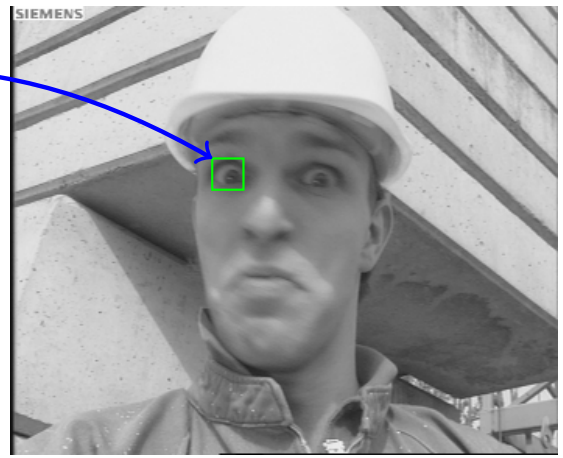
Motion Compensation

- Motion compensation interpolates a predictor from a past (and/or future) frame based on the MV.
- Predicting from a single past frame is also called *unidirectional prediction*.

74	72	74	73
90	93	92	91
102	100	99	100
106	106	104	105



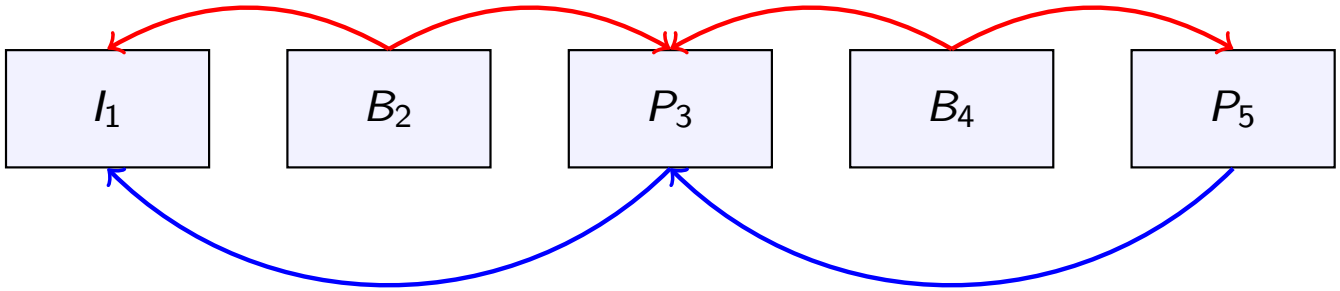
74	72	74 +1	73 +5
90	93	92 +2	91 +3
102	100	99 -1	100 -1
106	106	104 +3	105 +1



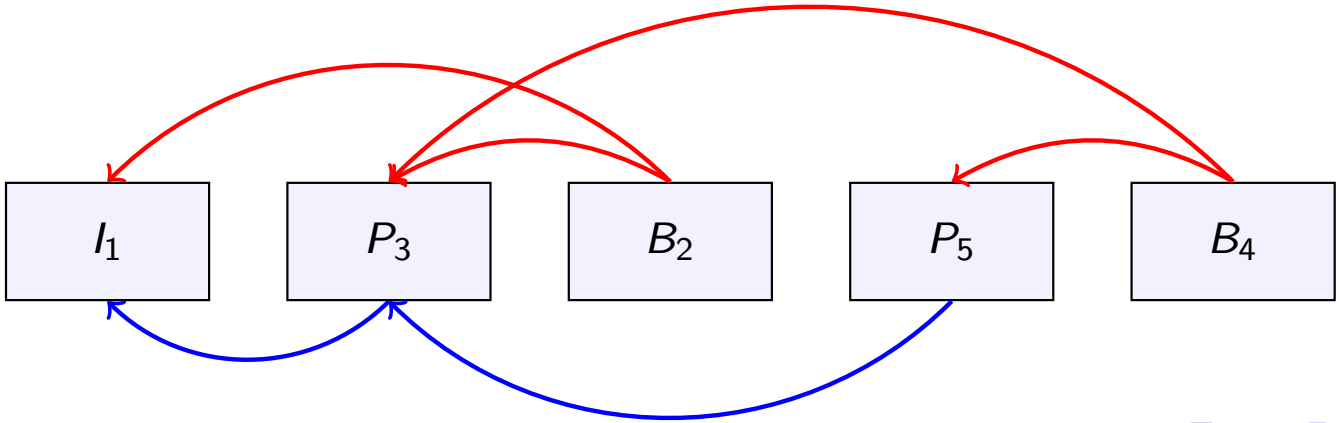
74	72	75	78
90	93 +1	94	94
102 -1	100 -3	98	99
106 +1	106 -2	107	106

Bidirectional Prediction

- Predicting from both a past frame and a future frame is called *bidirectional prediction*.

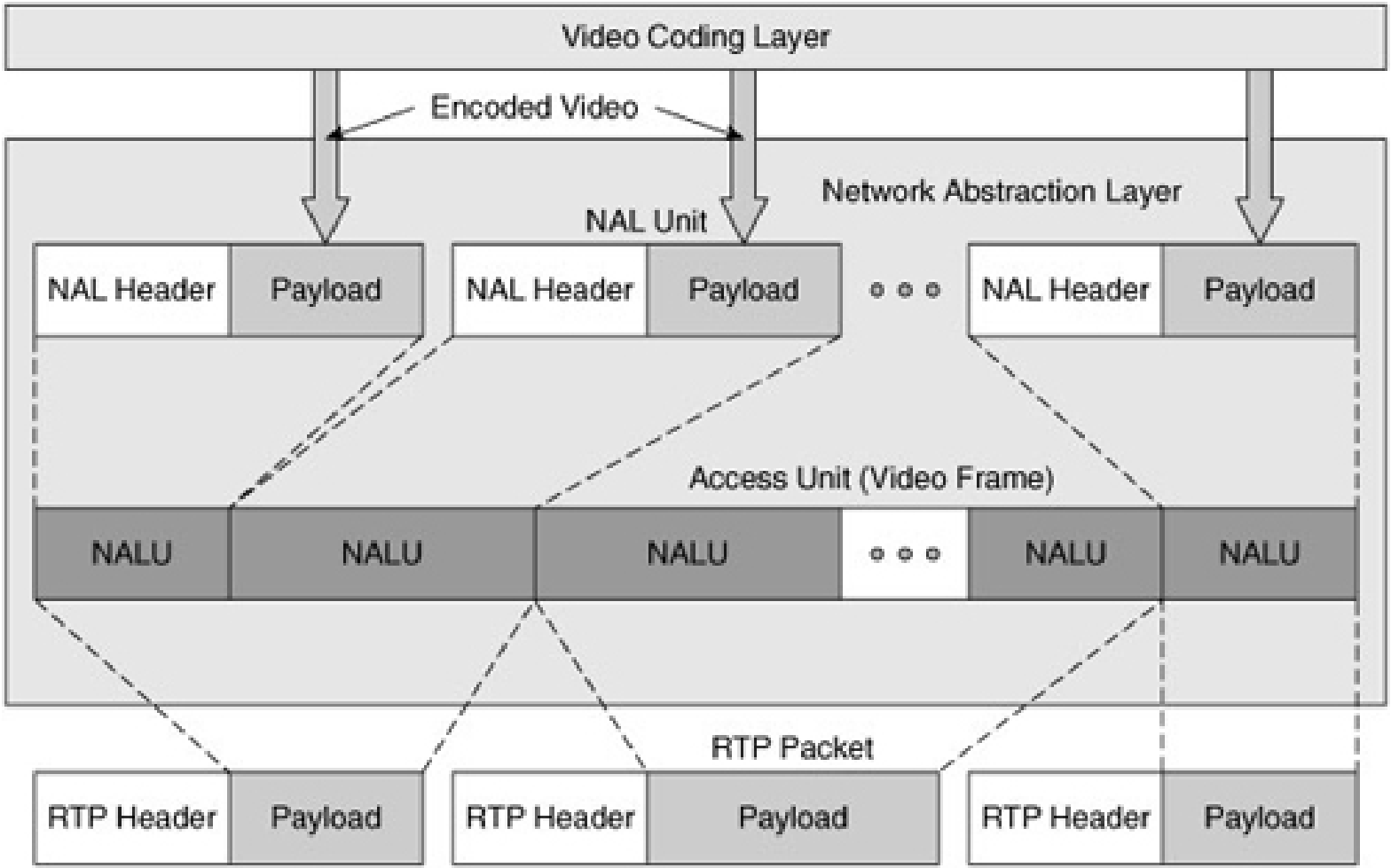


Display order.



Packetization

- Compressed video is packetized for network transmission



What Happens When Packets Are Lost

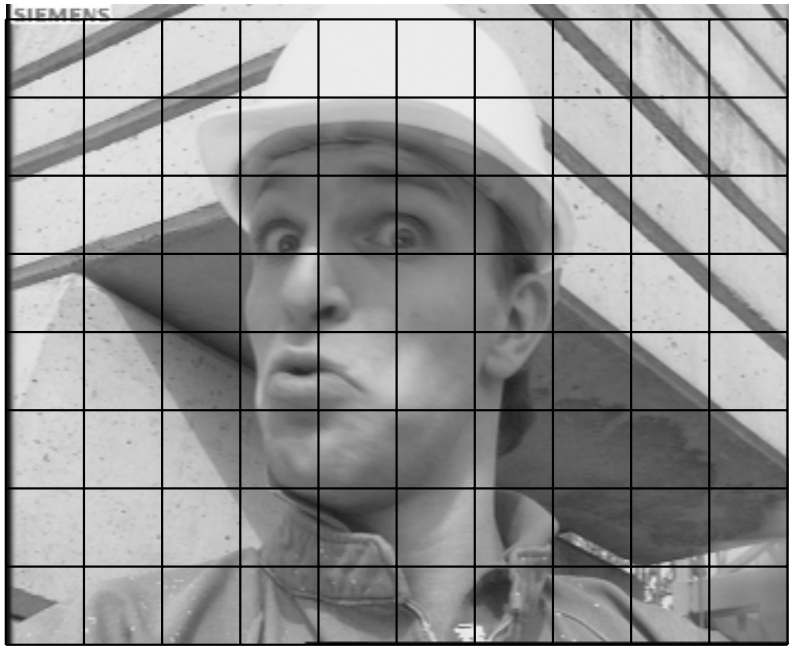
- Loss of compressed video data results in *encoder decoder mismatch* – the encoder encodes something and transmits it, but the receiver never receives it, and thus can't show it. A "dropped" or broken frame will be the result.
- Worse, the encoder assumes the decoder has it, and codes future frame frames referring to it, widening the "mismatch" with each frame. Persistent "smearing" artifacts will be the result.

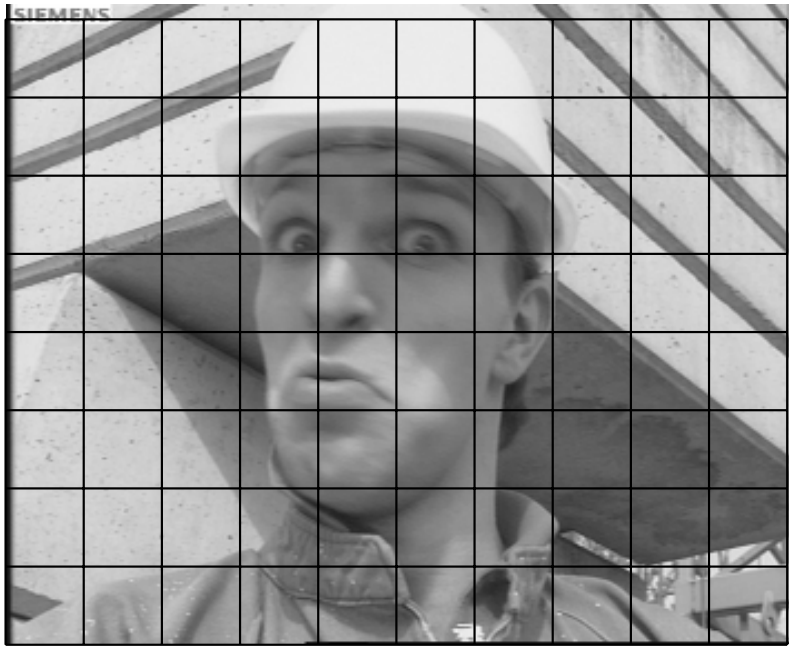
No packet losses

Mismatched decode due to packet loss

Concealment Algorithms

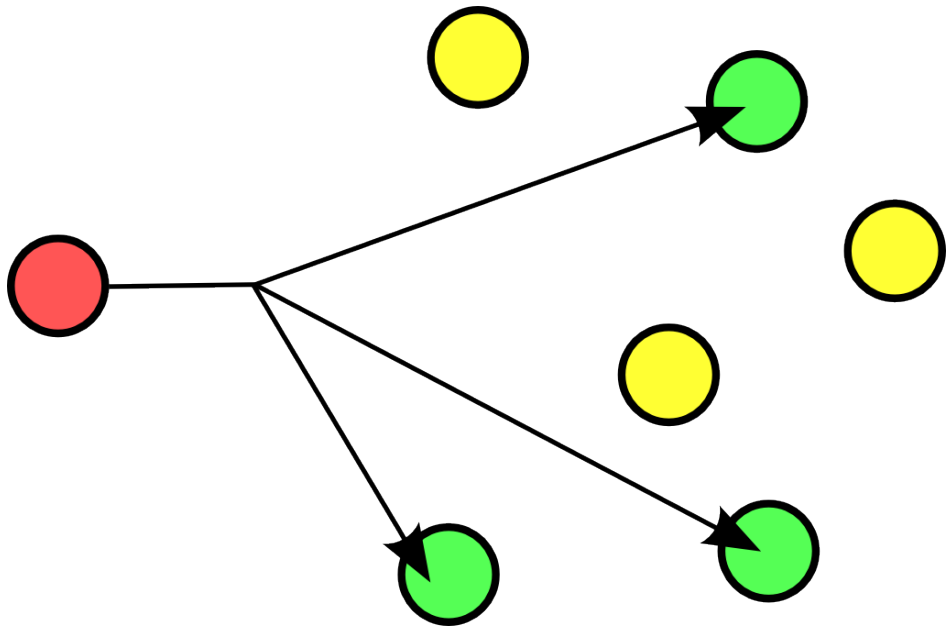
- Packet redundancy – Adaptive Slice Ordering (ASO)
- Patterned coding (e.g., checkerboard) – Flexible Macroblock Ordering (FMO)
- Joint source-channel coding – Trellis Coding



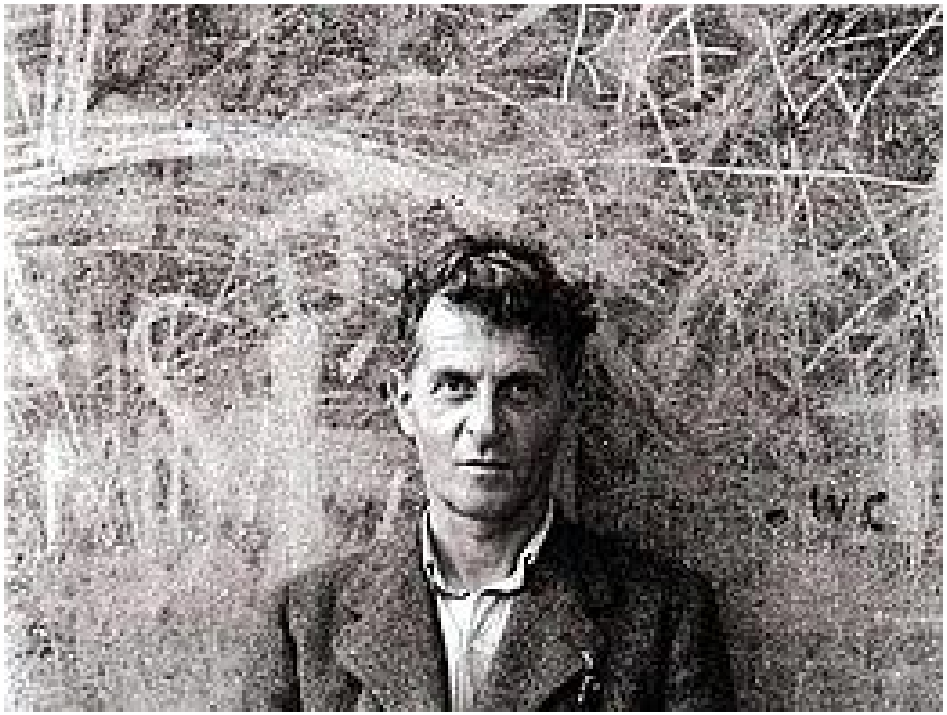


IPTV vs OTT

- OTT is simply streaming over TCP
- IPTV is *multicast* over *UDP* – especially susceptible to loss
- WiFi doesn't do multicast ☺
- Multicast to Unicast on root WiFi node



Remember Context



Loss is a part of life ☺