Dual Wi-Fi: Dual Channel Wi-Fi for Congested WLANs with Asymmetric Traffic Loads

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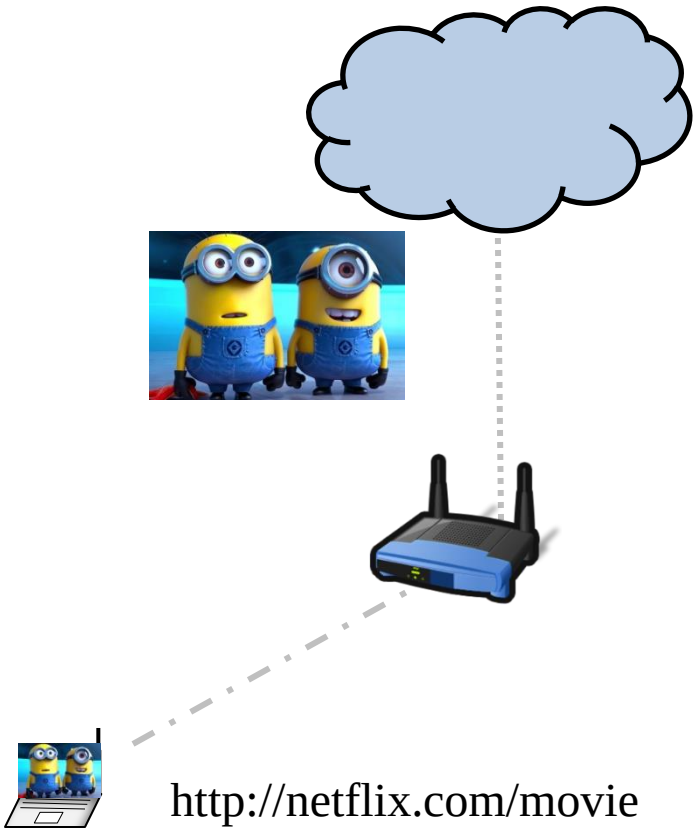
Motivation



- **Traffic Asymmetric**
- Downlink traffic >> Uplink Traffic

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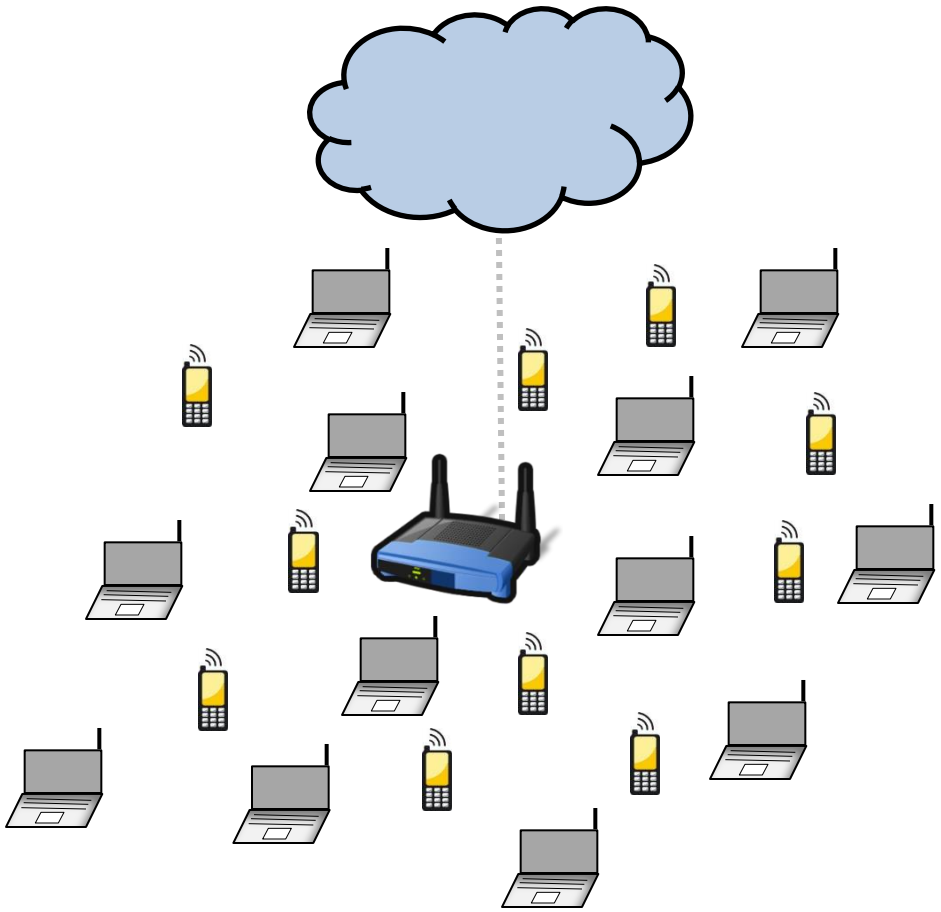

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- High number of backlogged nodes competing for the same resources

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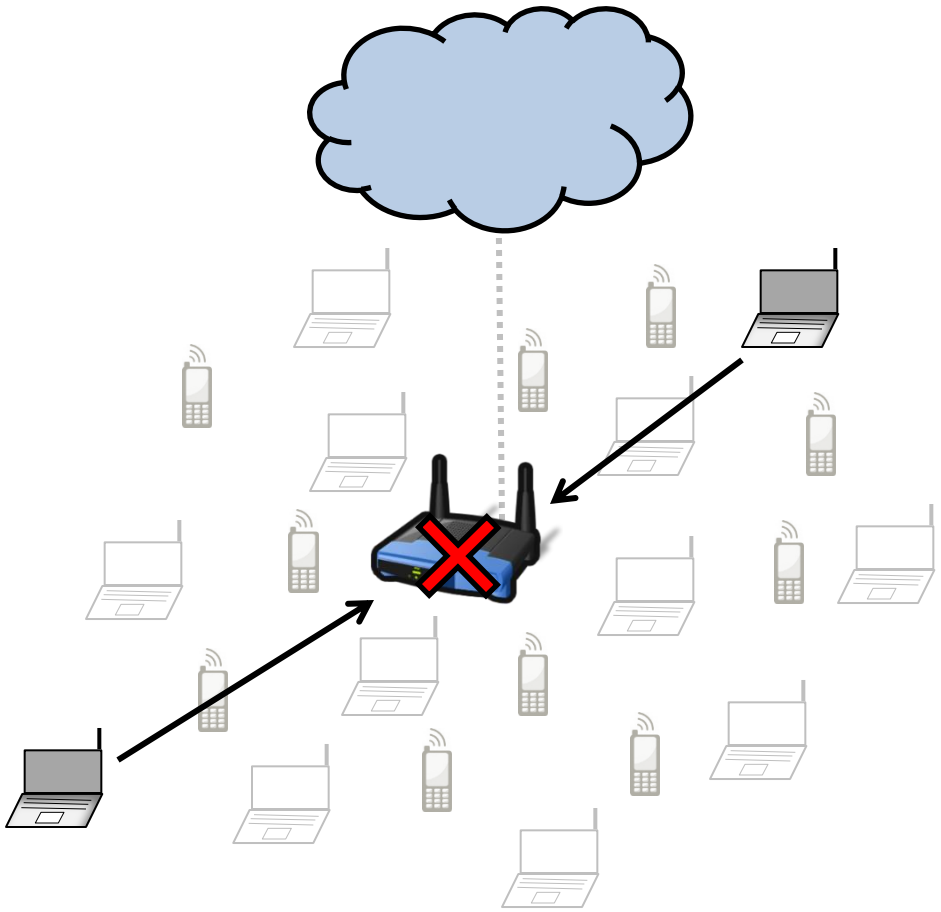

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- **Hidden Terminals**
- Cause collisions
- Spectrum Underutilization
- Affects downlink

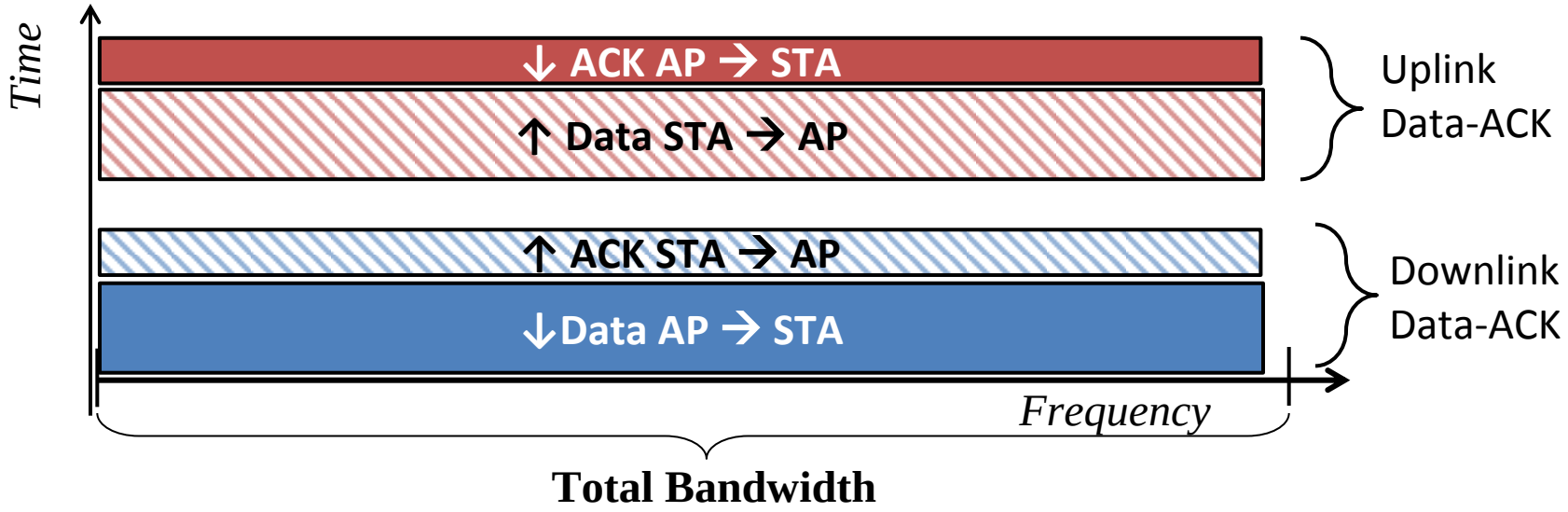
802.11 in Congested WLANs with Traffic Asymmetry

- **Shared resources**
  - Defer to one another transmissions
  - Performance dependency
    - Spectrum Underutilization (Coordination Time, Collisions)
    - E.g. Collisions by Hidden Terminals
- **Disproportionate contention**
  - Uplink Data: many clients vs. Downlink Data: few APs
  - Same CWmin yields equal medium access probability
    - N backlogged Clients :
      - Uplink Data: N/(N+1) Downlink Data: 1/(N+1)

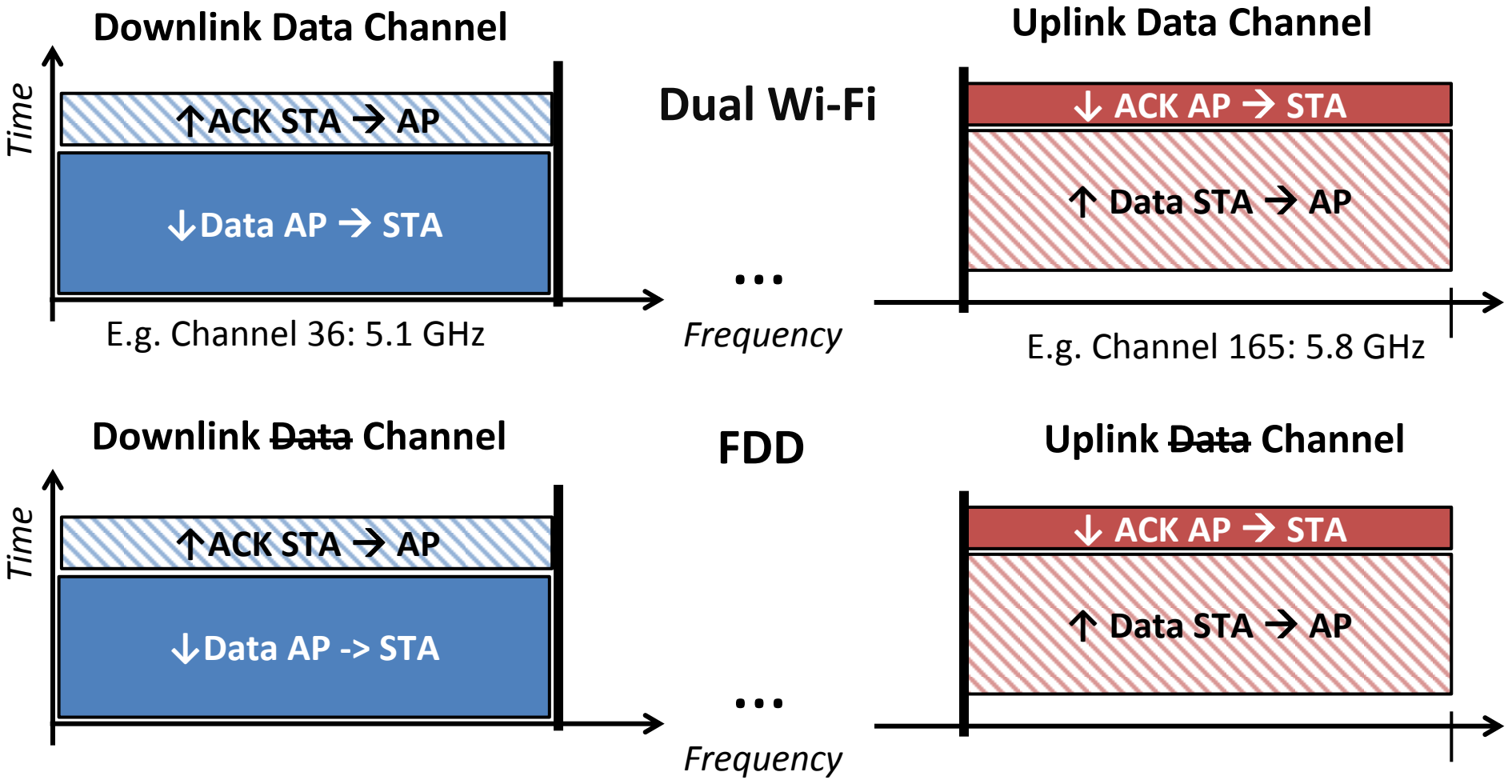
Goal

- Define a random access MAC that provides configurable spectrum resources for upload vs. download traffic
  - Enables matching resources to demand
  - Enables high spectral efficiency

802.11 Channel Architecture



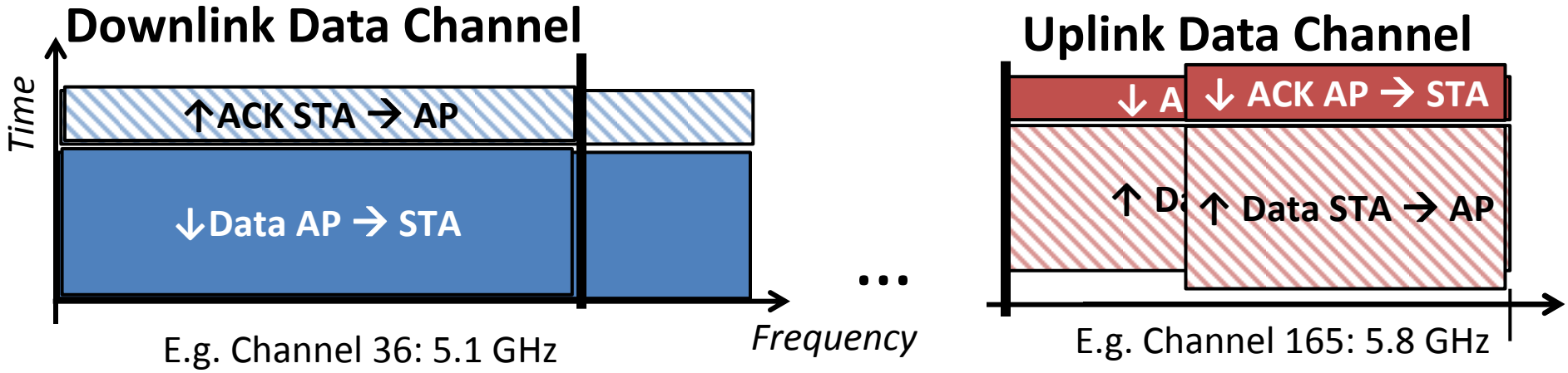
Dual Wi-Fi Channel Architecture



Features of Dual Wi-Fi Channel Architecture

- **Logical Division (direction of data)**
  - Decouple medium access
    - Medium access directly weighted on the traffic load of that direction
  - Independent and asynchronous operation
  - Independent performance
  - Independent resource allocation
  - Flexible bandwidth division
- **Bi-directional traffic within channels**
  - Support the complete MAC-layer Data-ACK handshake
  - In-channel control feedback
    - paired with transmitted data
    - Unlike FDD, no generic control messages use the channel

Dual Wi-Fi Benefits



- Match spectrum resources to **traffic asymmetry**
- **Contention asymmetry:** remove uplink and downlink competition for the same spectrum resources
- Reduce medium contention and collisions

  → Increase spectral efficiency

Dual Wi-Fi MAC

- Isolate downlink and uplink medium access
  - Dual Wi-Fi ensures APs do not contend with STAs
- 802.11 CSMA basic access

Downlink Data Channel

- Only same-channel *APs*
- CW still necessary
- CW size tune to # of in-channel APs
  - *1 AP*:
    - Collision-Free
    - No Contention

Uplink Data Channel

- Only *STAs*
- Remove contention with heavy downlink traffic

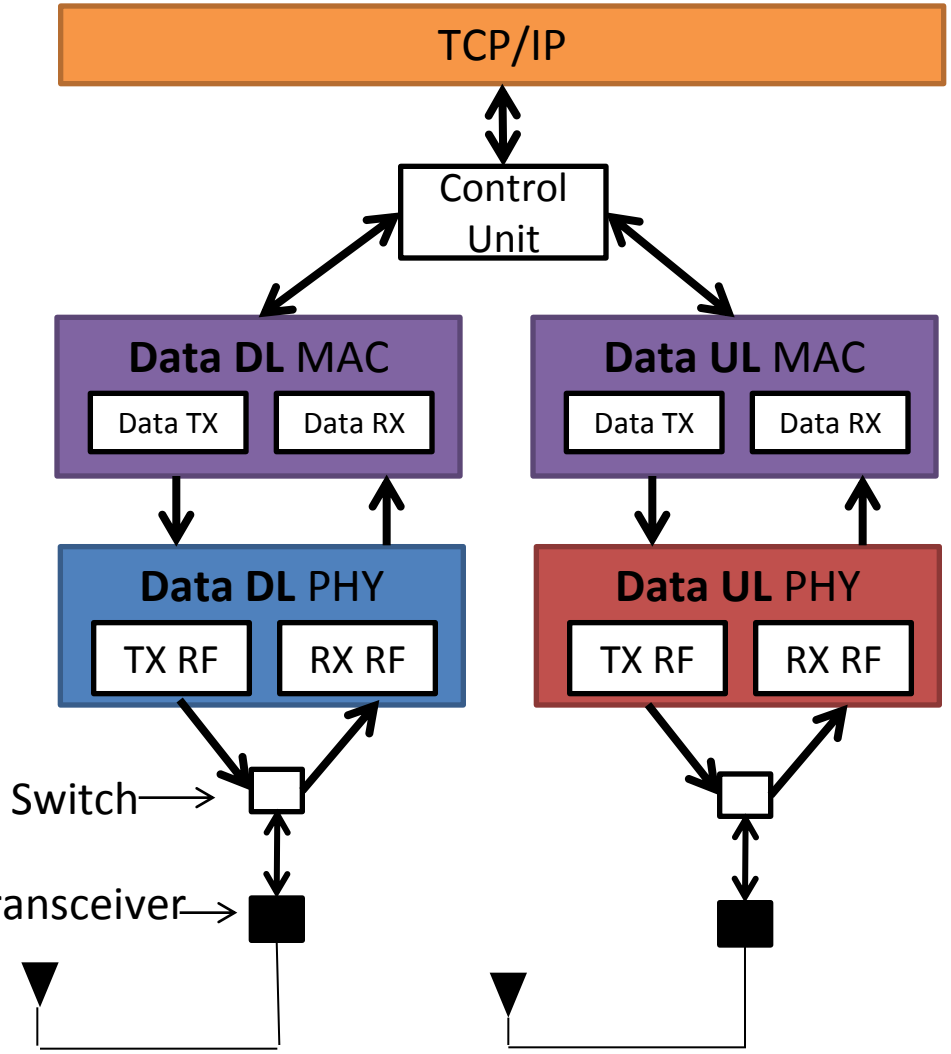
Smaller number of contending nodes per channel:
↓ Coordination time, collisions and retransmissions
→ Increased spectral efficiency

Dual Wi-Fi vs. EDCA variation

- Identify downlink data traffic as high-priority traffic providing strict or partial priority to APs to access the medium
- **Advantage:**
  - Counters traffic asymmetry with minimal protocol modifications
- **Disadvantages:**
  - *Issues of shared band:*
  - Medium Access aggressiveness
    - Dependency in number STAs and load
  - Coupled Medium Access
    - Downlink transmissions must defer to uplink transmissions
  - Coupled Performance
    - Throughput fraction is dependent on the load
      - Lead to starvation
    - Collisions
  - No guaranteed resources provided to downlink data traffic

Dual Wi-Fi Node Architecture

- Two radio approach
  - Clients and APs
  - Tx and Rx in each channel independently and asynchronously
  - Full Duplex
    - (Different frequencies)
  - Co-channel Interference
    - Guard Band
      - WiFi-NC :100 KHz

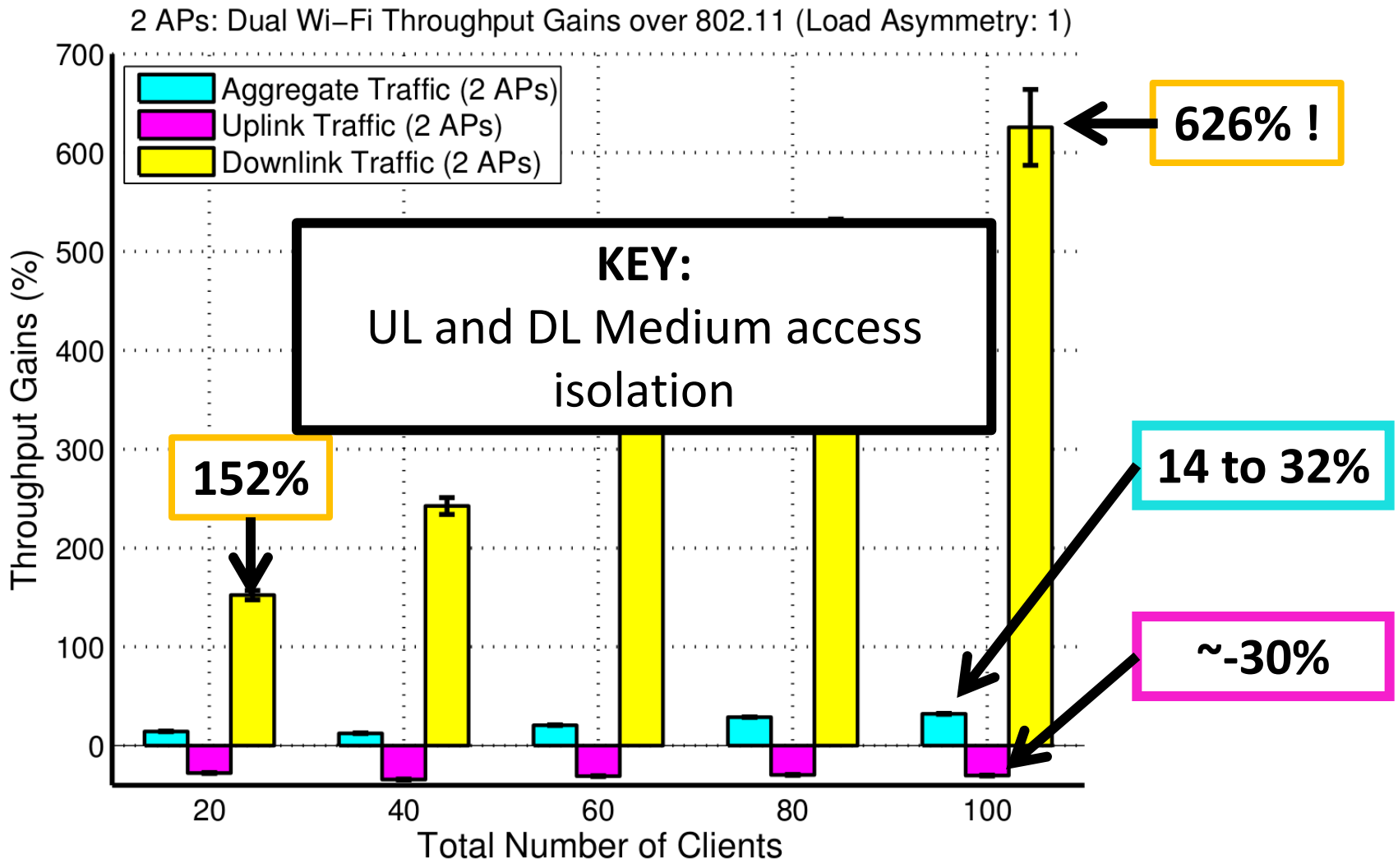


Node Architecture Design Alternatives

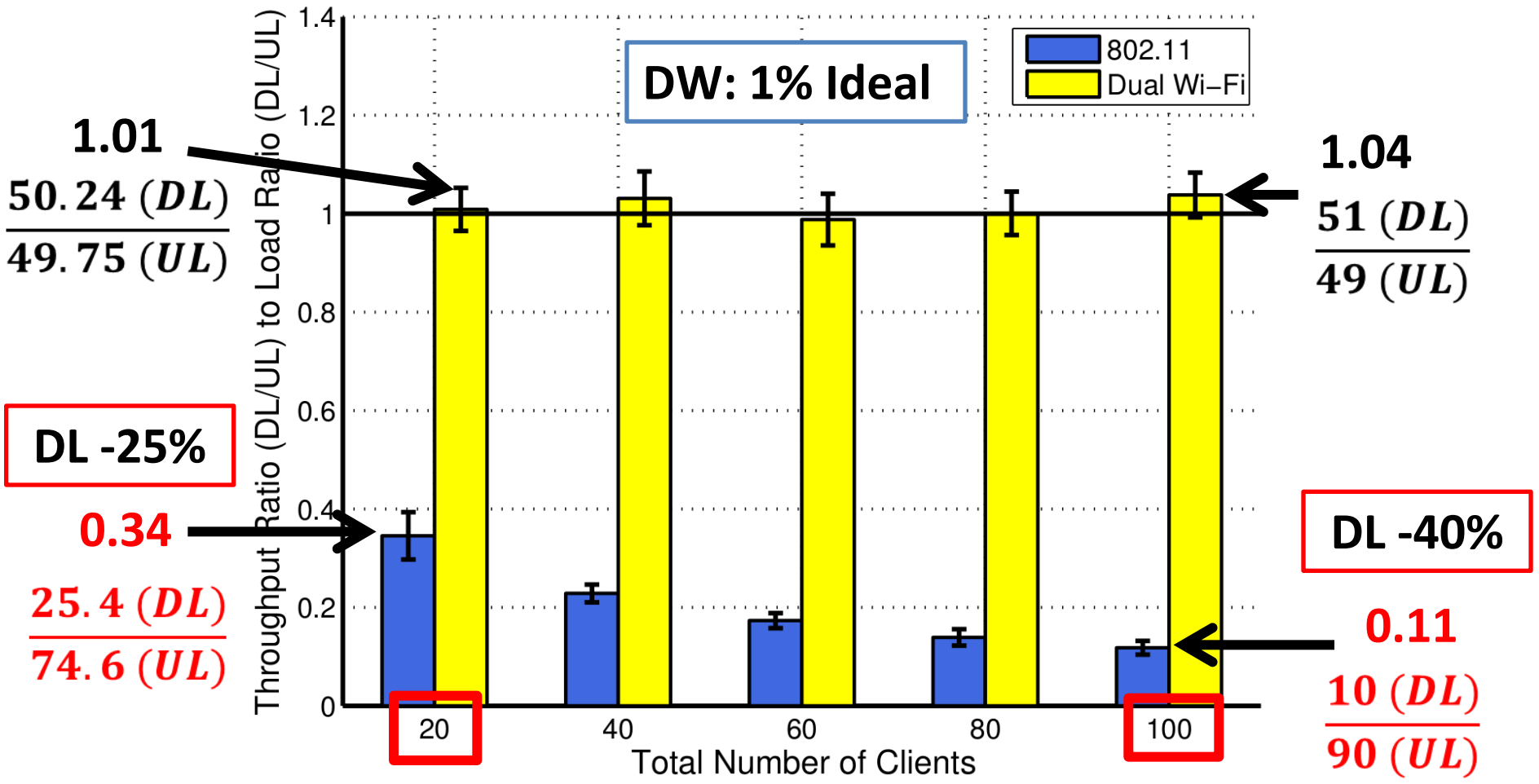
- **Half-Duplex Clients**
  - AP smart selection of downlink data transmissions
    - Transmit to clients which it is not currently receiving from

1. Single radio clients
   - Only Tx or Rx in a single channel at a time
   - Filter to select either channel
2. Dual radio clients
   - Only Tx or Rx in a single channel at a time
   - Only operate a single radio at a time
     - Avoid cross talk

Dual Wi-Fi Performance Gains



Impact of Contention Asymmetry



Conclusion

- Spectrum independence between uplink and downlink MAC data traffic
  - Can provide performance that is proportional to imposed demand
  - Adaptable to any **traffic asymmetry** or **network density**
- Flexible design that adapts to changes in actual usage

- **Applications**
  - Efficient use of resources
  - Key solution to address congested scenarios
    - White Spaces – isolation of hidden terminals
  - Faster downlink data delivery – Traffic asymmetry