

Resilience in 5G

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Sources of errors and countermeasures

- Small-scale fading:
 - Assumed in most theoretical papers
 - Countermeasures: antenna diversity, frequency diversity, temporal diversity (including HARQ)
 - What is different in 5G:
 - Less relevant for massive MIMO (channel hardening)
 - Less relevant for mm-Wave (LOS or dominant reflected component (?))
 - More relevant for short packets (less frequency/time diversity)

Sources of errors and countermeasures (2)

- Large-scale fading:
 - Shadowing due to
 - Environmental objects (buildings)
 - Dynamic obstacles
 - Body shadowing by person/robot holding device
 - Shadowing by hand
 - Importance in 5G:
 - More important at mm-wave (larger shadowing variances)
 - URLLC more sensitive to shadowing errors (no time to correct)
 - Possible solution: multi-band diversity (e.g., 2 GHz and mm-wave)

Sources of errors and countermeasures (3)

- Delay spread:
 - Causes: multipath
 - Advantage when providing additional diversity
 - Requires significant signal processing
 - Becomes obstacle when signal processing limited
 - Relevance in 5G
 - Can be deadly for high data rates: e.g., 1ns delay spread at 100 Gbaud/s
 - Countermeasures: beamforming, analog equalizers
- Phase noise:
 - Causes: Doppler, and LO noise
 - Relevance in 5G:
 - Enhanced for mm-wave systems

Beamtracking and channel tracking

- Optimum beam direction can be quickly outdated:
 - Causes
 - Movement of TX/RX
 - Dynamic obstacle blocking preferred direction
 - Rotation of body holding device
 - Relevance in 5G:
 - Enhanced, due to narrow beams (large arrays)
 - Countermeasures:
 - “fallback” beams, but 5G protocol is slow
 - Compressive sensing
 - ML prediction

Interference and coverage

- Coverage limited for 5G systems
 - Streets with different orientation have different pathloss coefficients, might need separate BS to cover them
 - New countermeasures: 3D network deployment (drones, satellites)
- Interference:
 - Interference limitation critical for high-density deployments
 - Cell-free massive MIMO provides less interference and macrodiversity
 - Issues of backhaul (reliability of link, overload) ?

Summary

- 5G has new challenges for resilience
 - High frequency -> shadowing, Doppler
 - Large arrays -> narrow beams make tracking difficult
 - URLLC has more stringent requirements (HARQ not applicable)
- While traditional small-scale fading becomes less relevant
- Need for new protocols and deployment