Degrees-of-Freedom of the MIMO Three-Way Channel with Node-Intermittency

Joachim Neu¹, Anas Chaaban², Aydin Sezgin³, Mohamed-Slim Alouini⁴
joachim.neu@tum.de, anas.chaaban@ubc.ca, aydin.sezgin@rub.de, slim.alouini@kaust.edu.sa

Abstract
Recent trends in wireless communications motivate the model of a multiple-input multiple-output (MIMO) three-way channel (3WC) with an intermittent node. We study its degrees-of-freedom (DoF) region and sum-DoF. We devise a non-adaptive encoding scheme and show its DoF region (and thus sum-DoF) optimality for non-intermittent 3WCs and its sum-DoF optimality for node-intermittent 3WCs. However, we show by counterexample that adaptive encoding is necessary to achieve the DoF region of node-intermittent 3WCs.

Introduction
Trends in Wireless
• Higher frequencies (mmWave)
  → Valuable but fragile line-of-sight
• Local communication (IoT, D2D, caching)
• Multiple antennas (MIMO)
• Interference-limited systems

Implications for Channel Models
✓ Interference channel as input
✓ Degrees-of-freedom (DoF) perspective
✓ Multi-way/device-to-device scenarios

Research Questions
• DoF region $\mathcal{G}$?
• Sum-DoF $\mathcal{G}_{\text{sum}}$?
• Necessity of adaptive encoding?

Contributions [-112]
• Sum-DoF of node-int. MIMO 3WC: $d_{\text{sum}} = 2\min\{d_1, d_2\} + 2\min\{d_1, d_2, d_3\}$ (tight)
• Necessity of adaptive encoding for DoF region of node-int. MIMO 3WC $\mathcal{G}_{\text{ni}}$:
  - Converse on $\mathcal{G}_{\text{ni}}$ (adaptive) and $\mathcal{G}_{\text{ni}}$ (non-adaptive)
  - Adaptive encoding scheme that achieves a $d_{\text{sum}}$-DoF outer bound $\mathcal{G}_{\text{ni}}$ (adapt)
• DoF Region $\mathcal{G}_{\text{ni}}$ of non-int. MIMO 3WC, $M_1 \geq M_2 \geq M_3$ (wlog):
  max $\{d_1 + d_2 + d_3, d_2 + d_3, d_1 + d_2\} \leq M_1$
  max $\{d_1 + d_2 + d_3, d_2 + d_3, d_1 + d_2\} \leq M_2$
  min $\{d_1, d_2, d_3\} \geq 0$
• Non-adaptive encoding suffices

System Model
$W_1 \leftarrow \{W_{11}, W_{12}, W_{13}\}$

DoF Region Counterexample
Let $M_1 \geq M_2 \geq M_3$, $N_{\text{MI}} \geq M_1$.

Converses
Partition the sum-DoF: $d_{\text{sum}} = d_1 + d_2 + d_3 + d_2 + d_3 + d_2 + d_2 + d_2 + d_2$

Converse (non-adaptive encoding)

Achievability (adaptive encoding)

Conclusion
• The presented non-adaptive encoding scheme...
  ... achieves $d_{\text{sum}}$-DoF of the node-intermittent channel
  ... achieves $\mathcal{G}_{\text{sum}}$-DoF of the node-intermittent channel
  → Non-adaptive encoding suffices for $d_{\text{sum}}$-DoF and $\mathcal{G}_{\text{sum}}$
  ... constitutes an inner bound $\mathcal{G}_{\text{ia}}$ for the node-intermittent channel
  • But any non-adaptive scheme provides only a strict inner bound for $\mathcal{G}_{\text{sum}}$
  → Adaptive encoding is necessary to achieve $\mathcal{G}_{\text{sum}}$

Key References

Chair for Digital Communication Systems
TUM – Technical University of Munich
Department of Electrical and Computer Engineering
Institute for Communications Engineering

IEEE Trans. Inf. Theory

Example for $M_1 \geq M_2 \geq M_3$. $M_1 \geq M_2 \geq M_3$. $M_2 \geq M_3$.