



SurePoint:

Exploiting Ultra Wideband Flooding and Diversity to
Provide Robust, High-Fidelity Indoor Localization

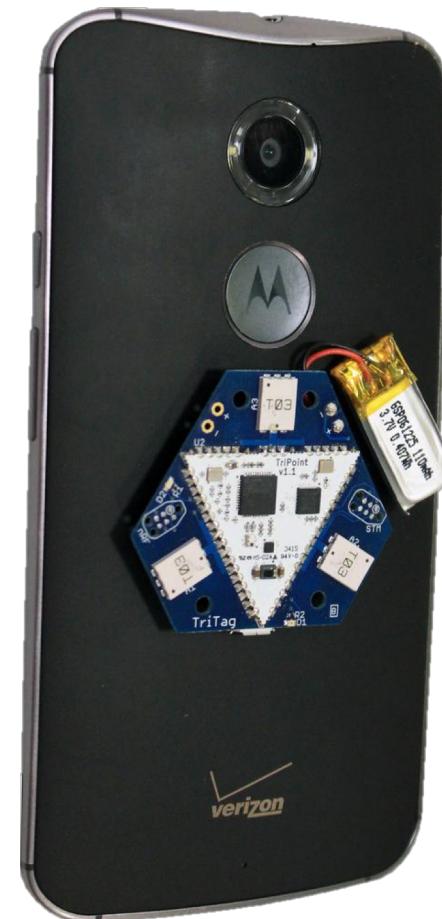
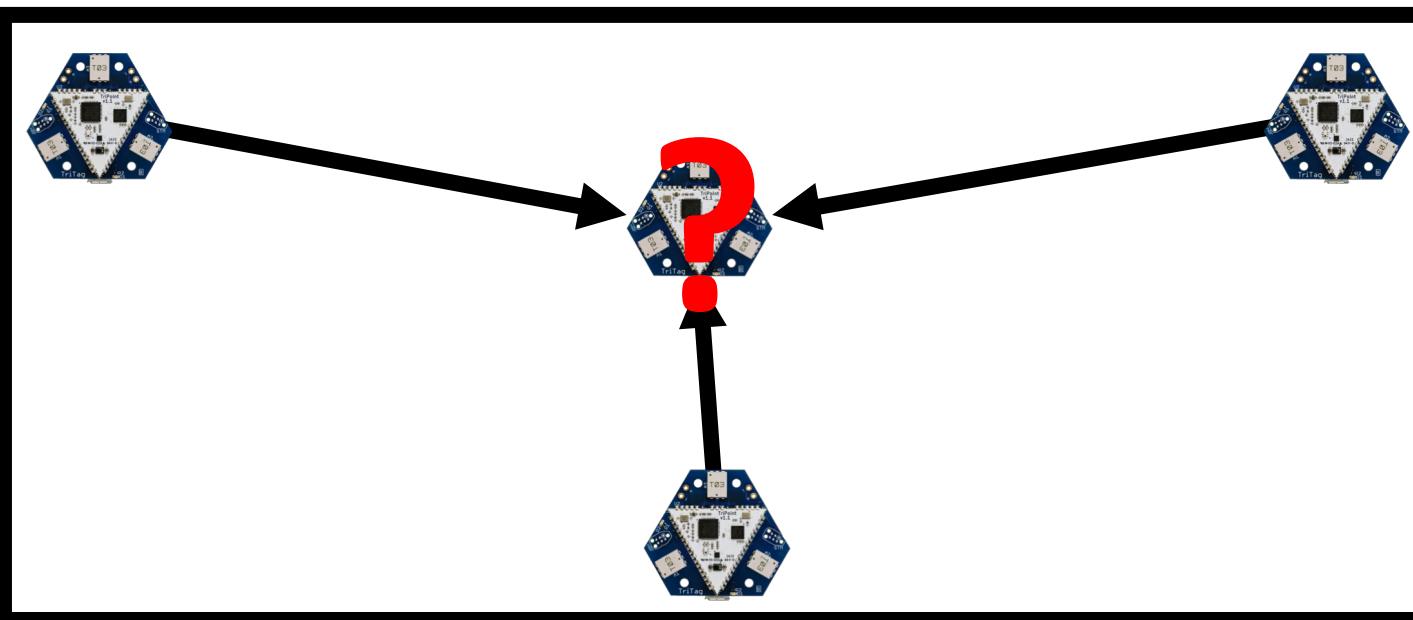
Electrical Engineering & Computer Science
University of Michigan



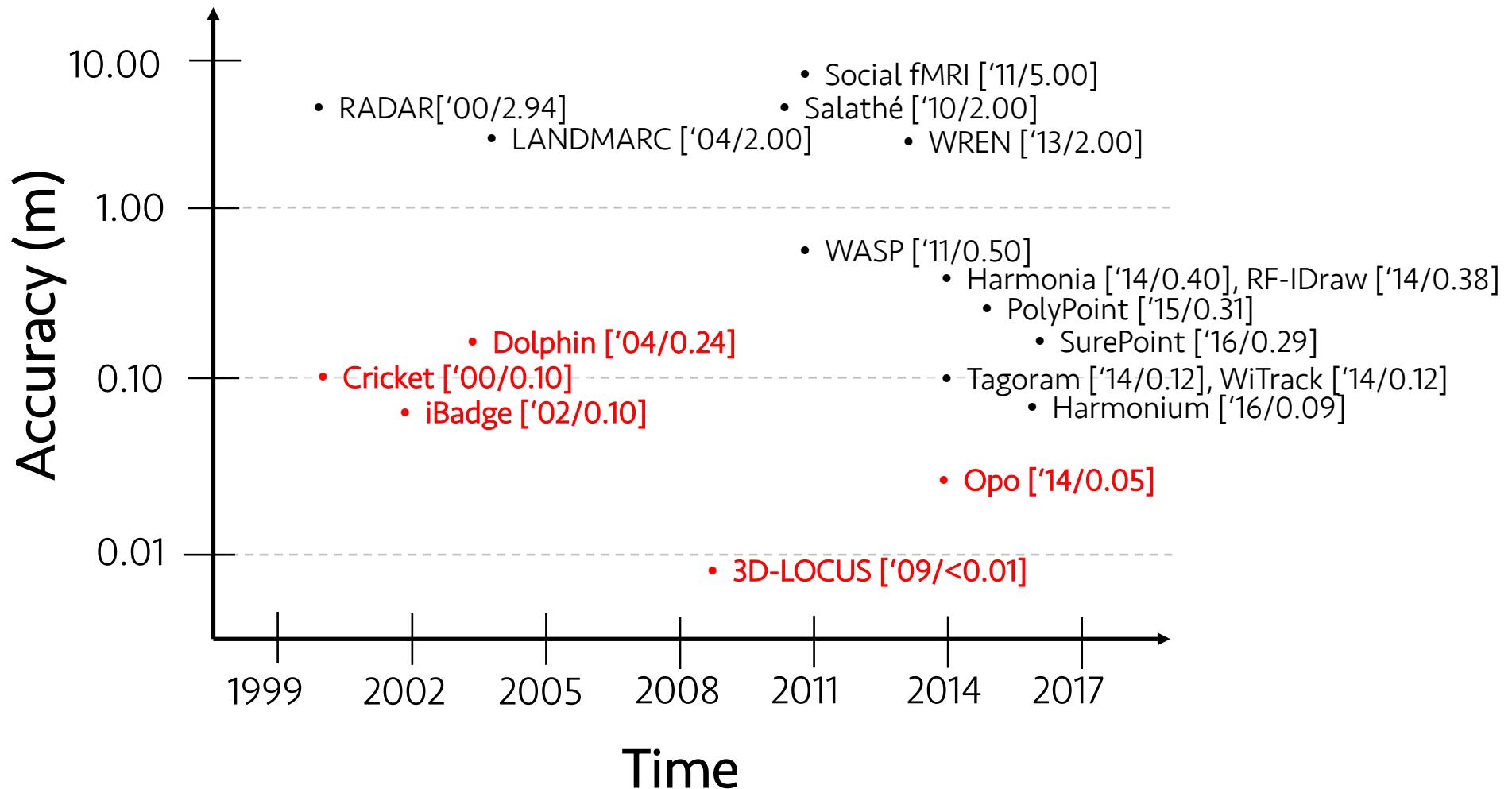
Benjamin Kempke
Pat Pannuto
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SurePoint: An Ultra-Wideband RF Localization System

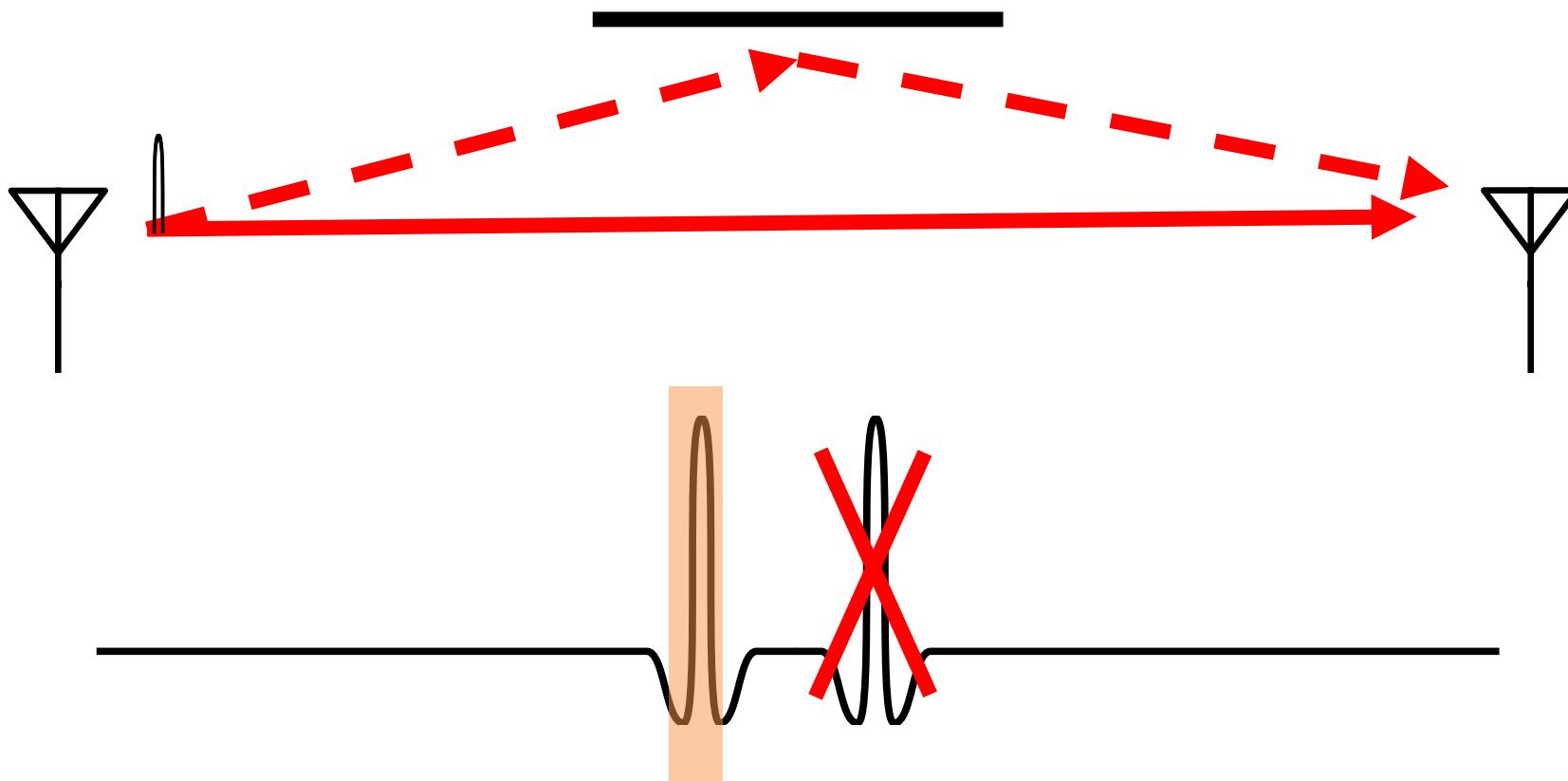
- SurePoint: a localization platform achieving high localization accuracy
 - 50% within 17 cm, 95% within 76 cm
 - Enabled by commercially-available UWB
 - *The Problem: Commodity UWB is a new technology with a number of limitations in its real-world implementation*



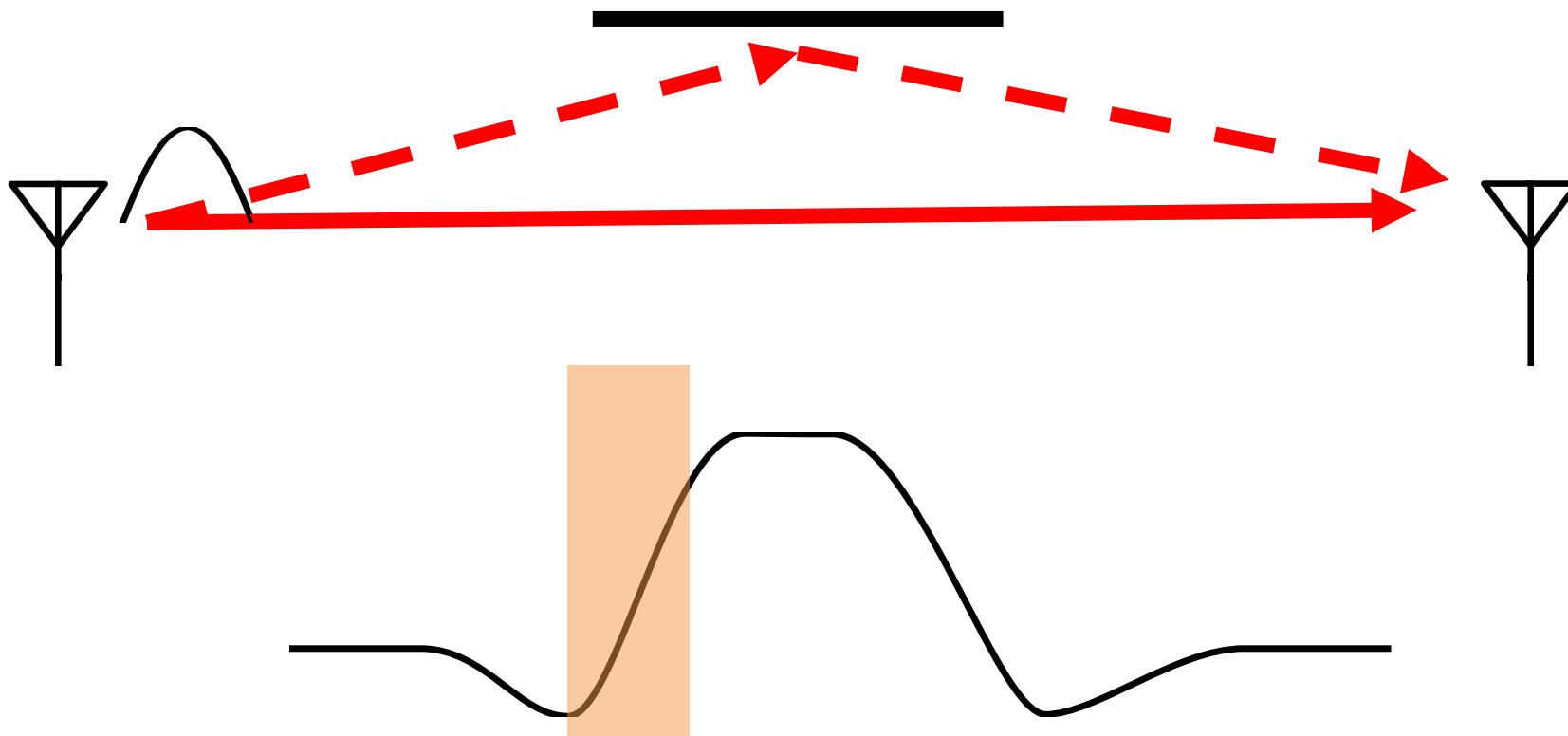
Highly accurate (RF-based) indoor localization technology has arrived



Why Does Ultra-Wideband Yield Better Localization Performance?



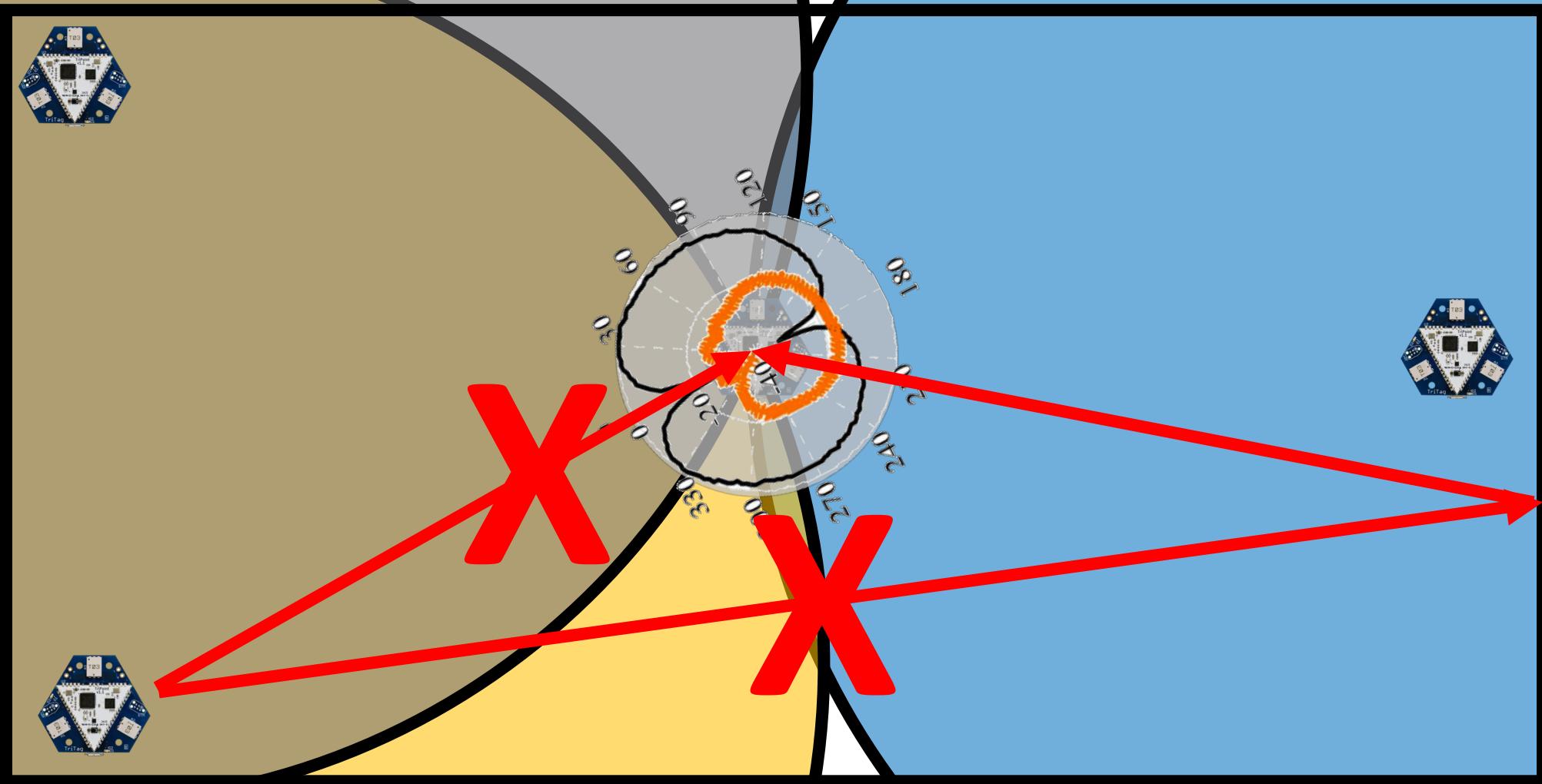
Why Does Ultra-Wideband Yield Better Localization Performance?



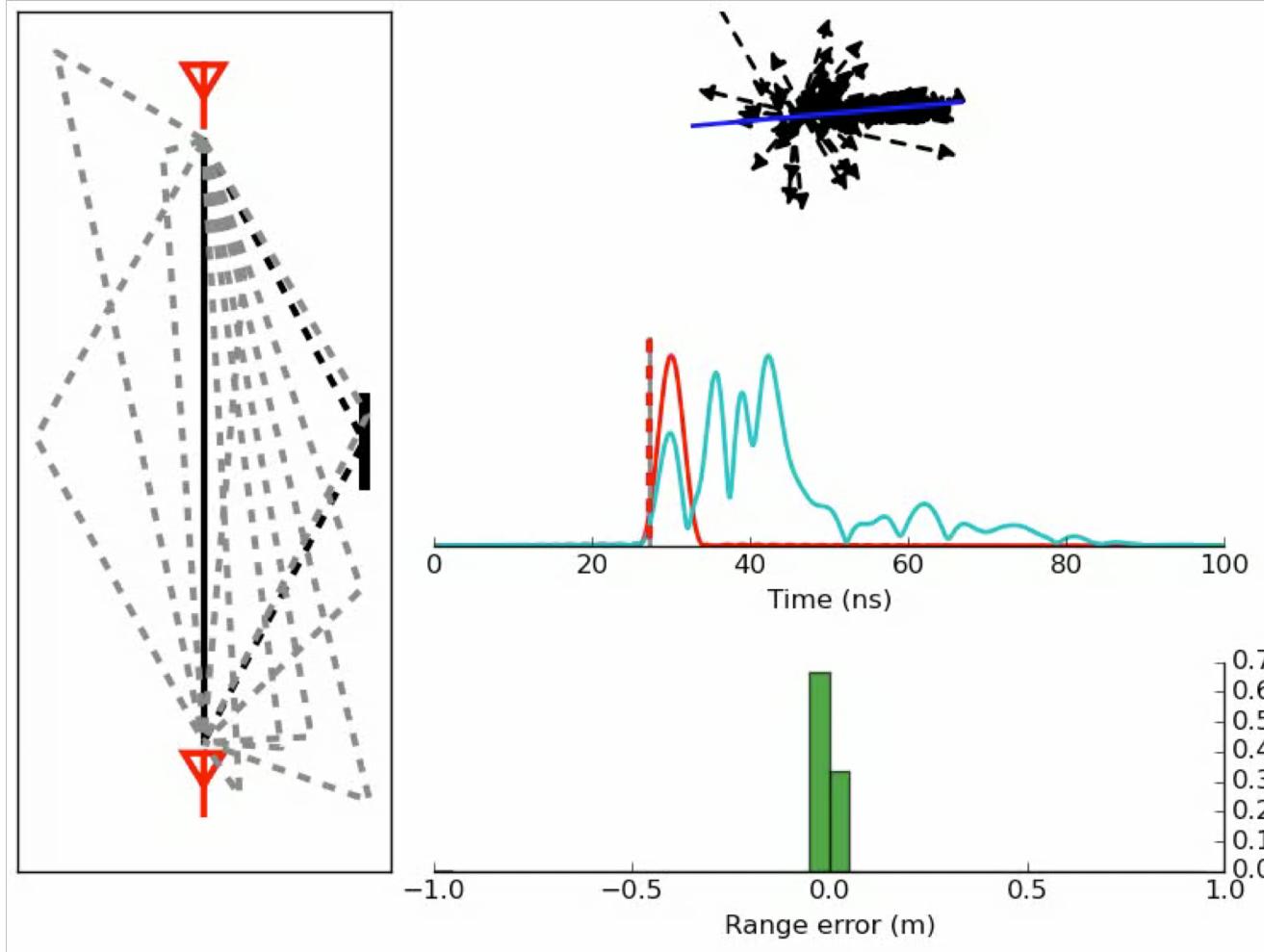
UWB: A Performant Technology with Significant Limitations

- Robustness
- Regulatory-limited Transmit Power
- Scalability
- Modularity

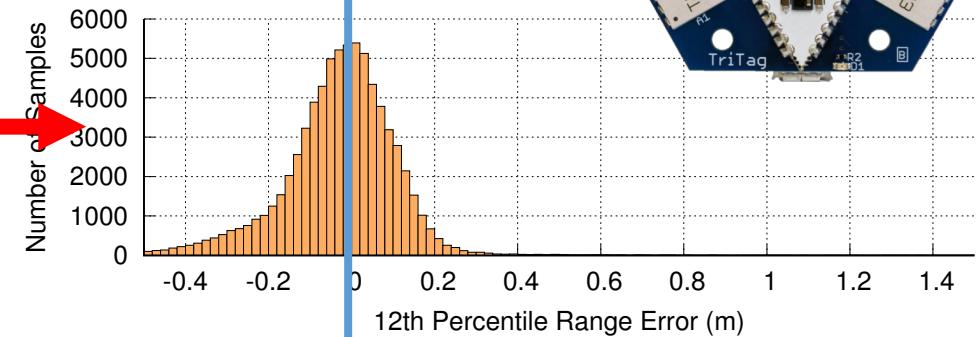
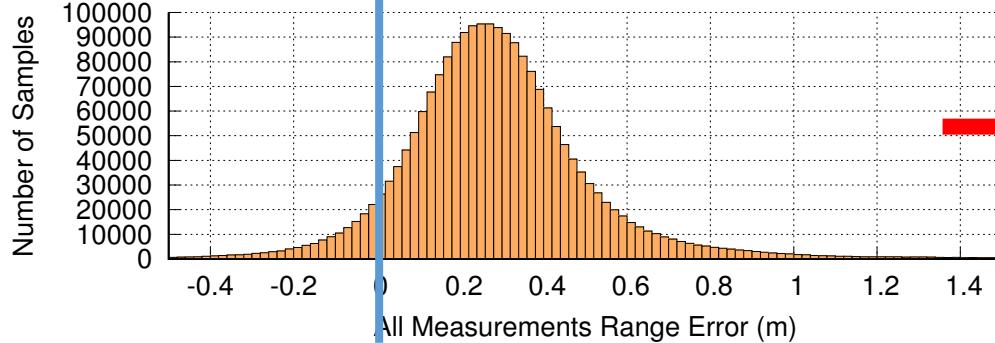
PolyPoint RF Localization System



The Need for Diversity In the Presence of Line-of-Sight



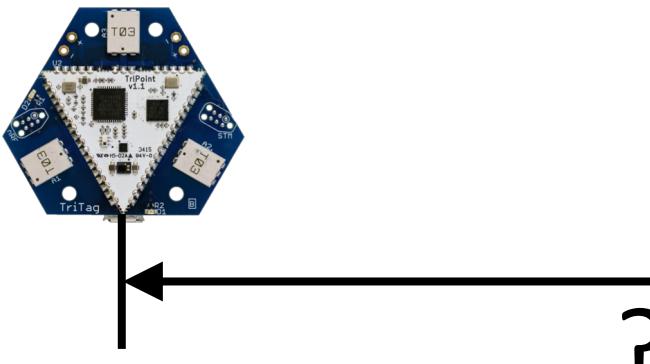
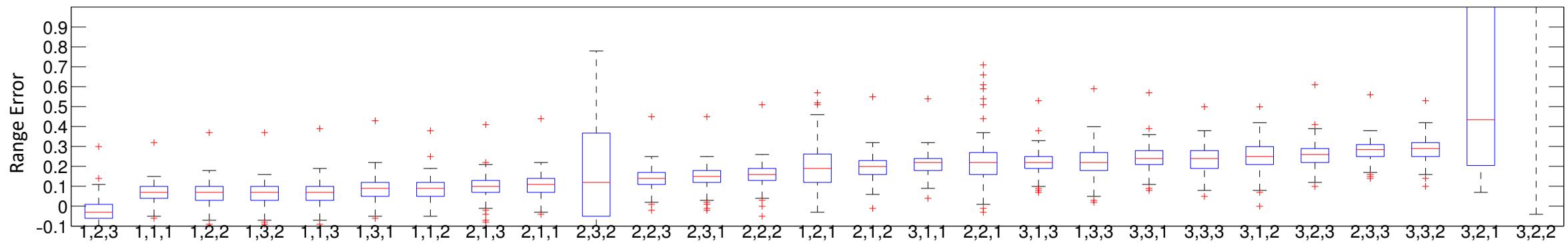
The Need for Diversity Measurements



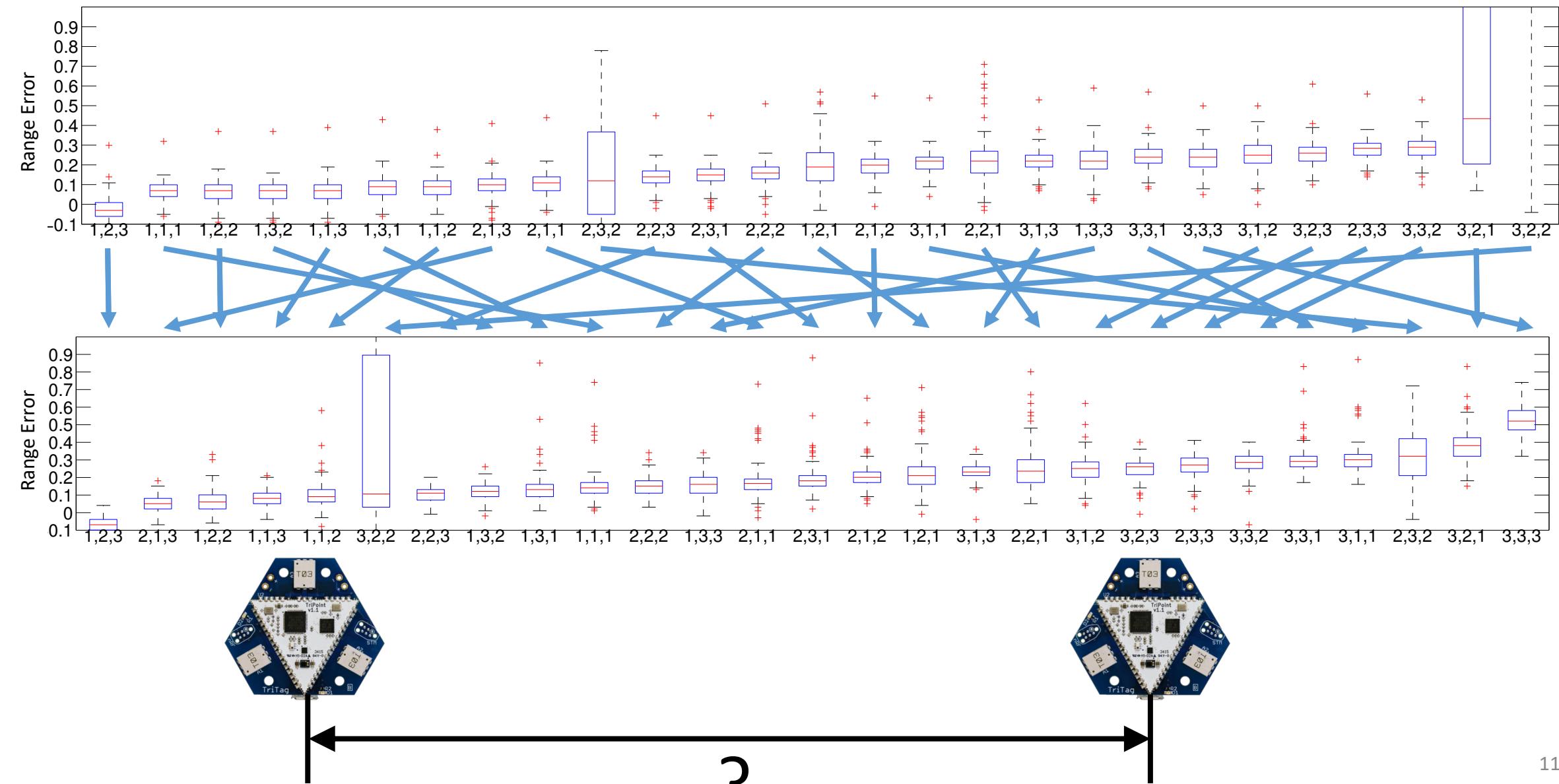
- 27 different observations of the RF channel
 - 3 tag antennas * 3 anchor antennas * 3 RF channels
- 12th percentile of range estimates used
 - yields zero-mean distribution of error in LoS environments

- Median ranging error:
 - 17 cm to 8 cm
- 95th percentile ranging error:
 - 65 cm to 34 cm

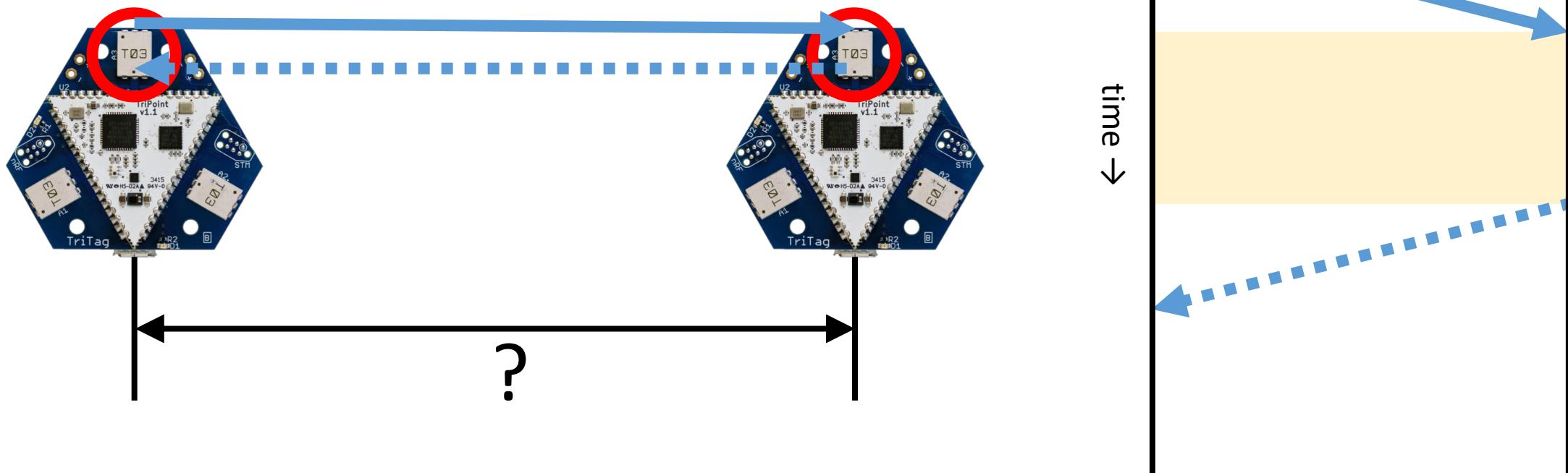
Ranging Error Stationarity



Ranging Error Stationarity

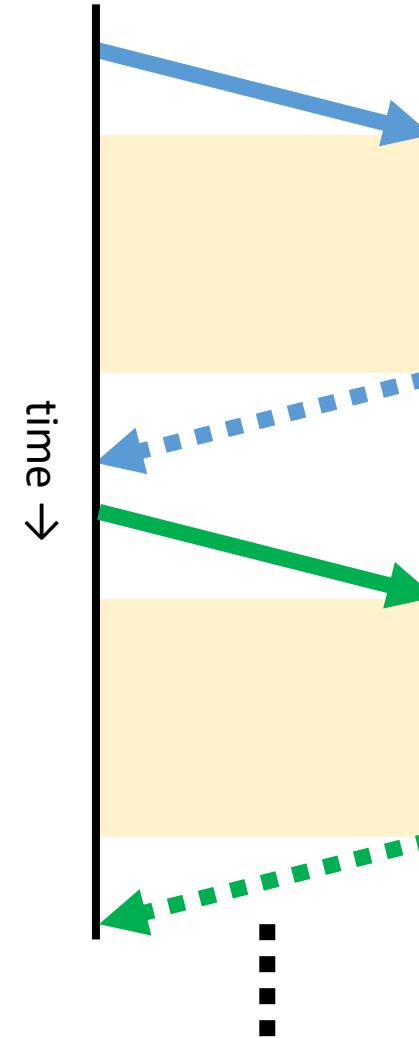
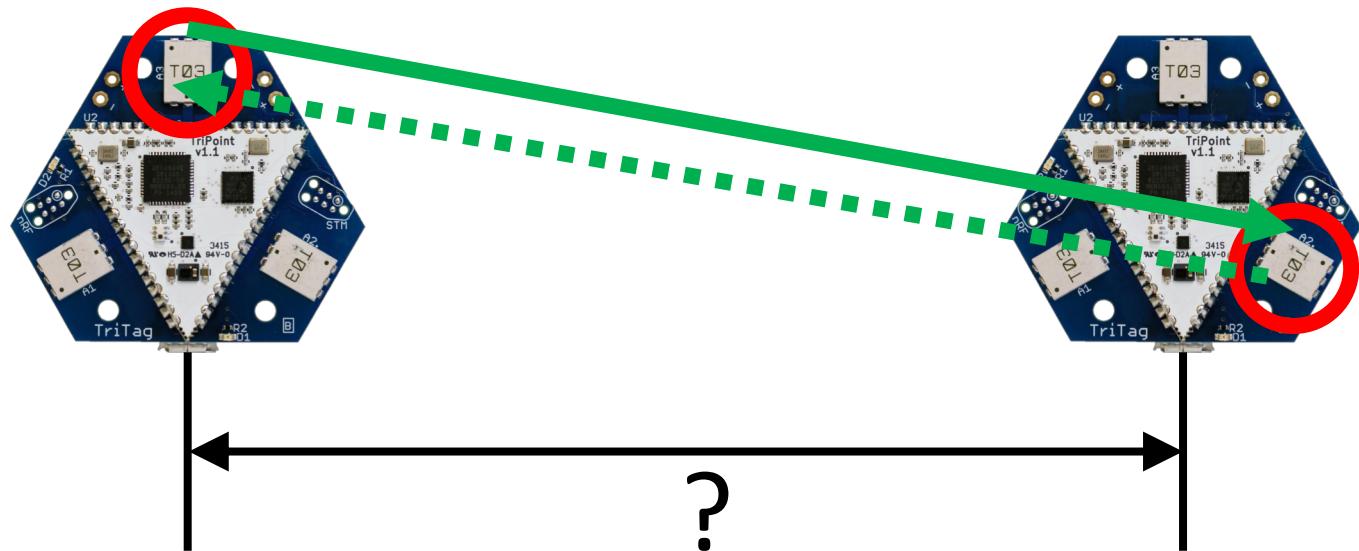


Measuring Range Using Two-Way Time-of-Flight

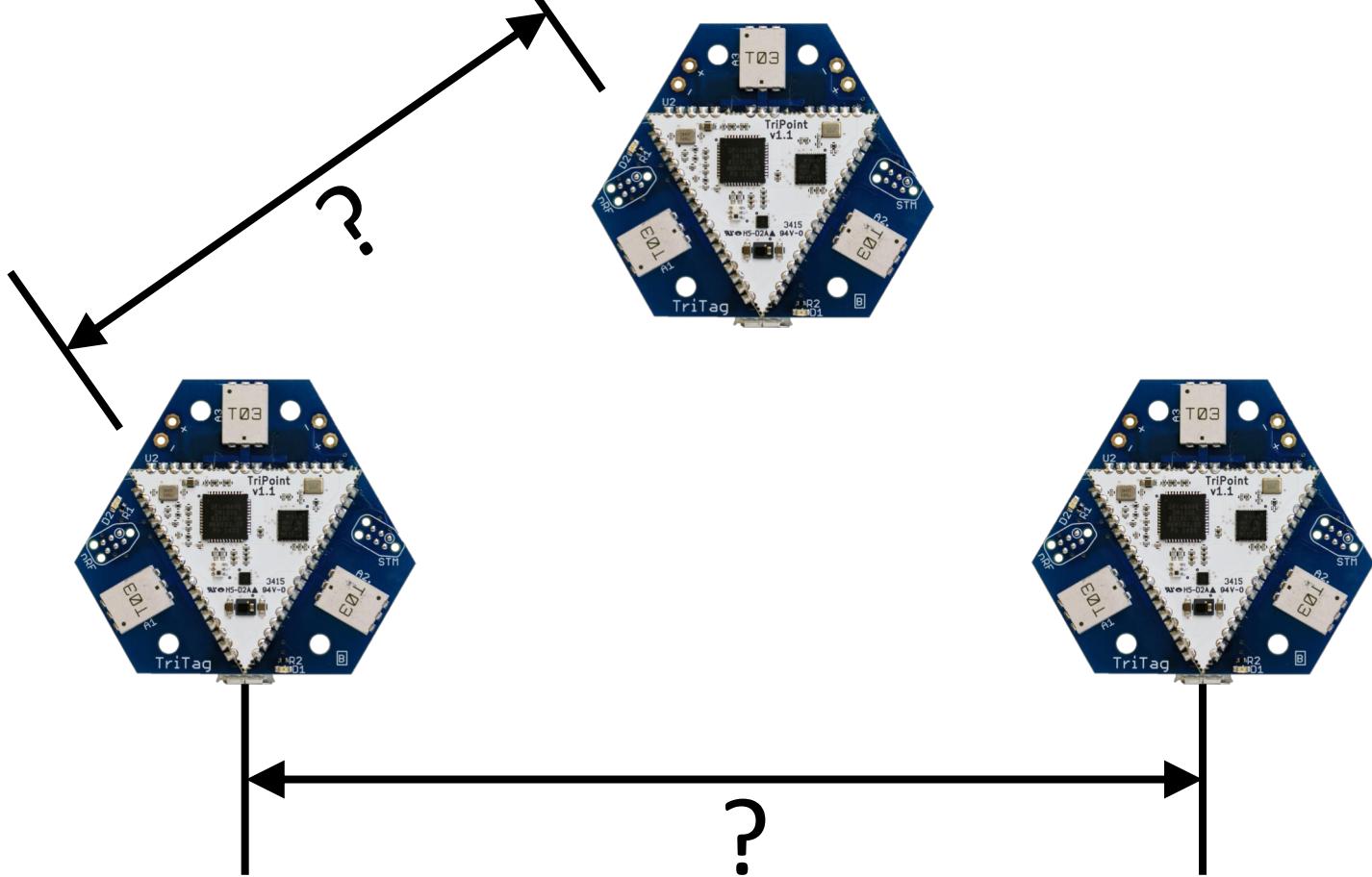


Efficiently Leveraging Diversity

$M = \# \text{ of measurements}$



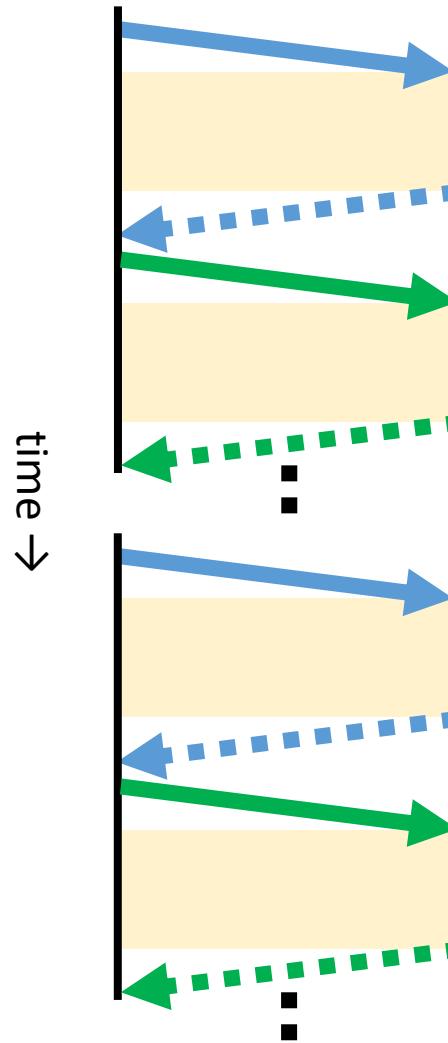
Efficiently Leveraging Diversity



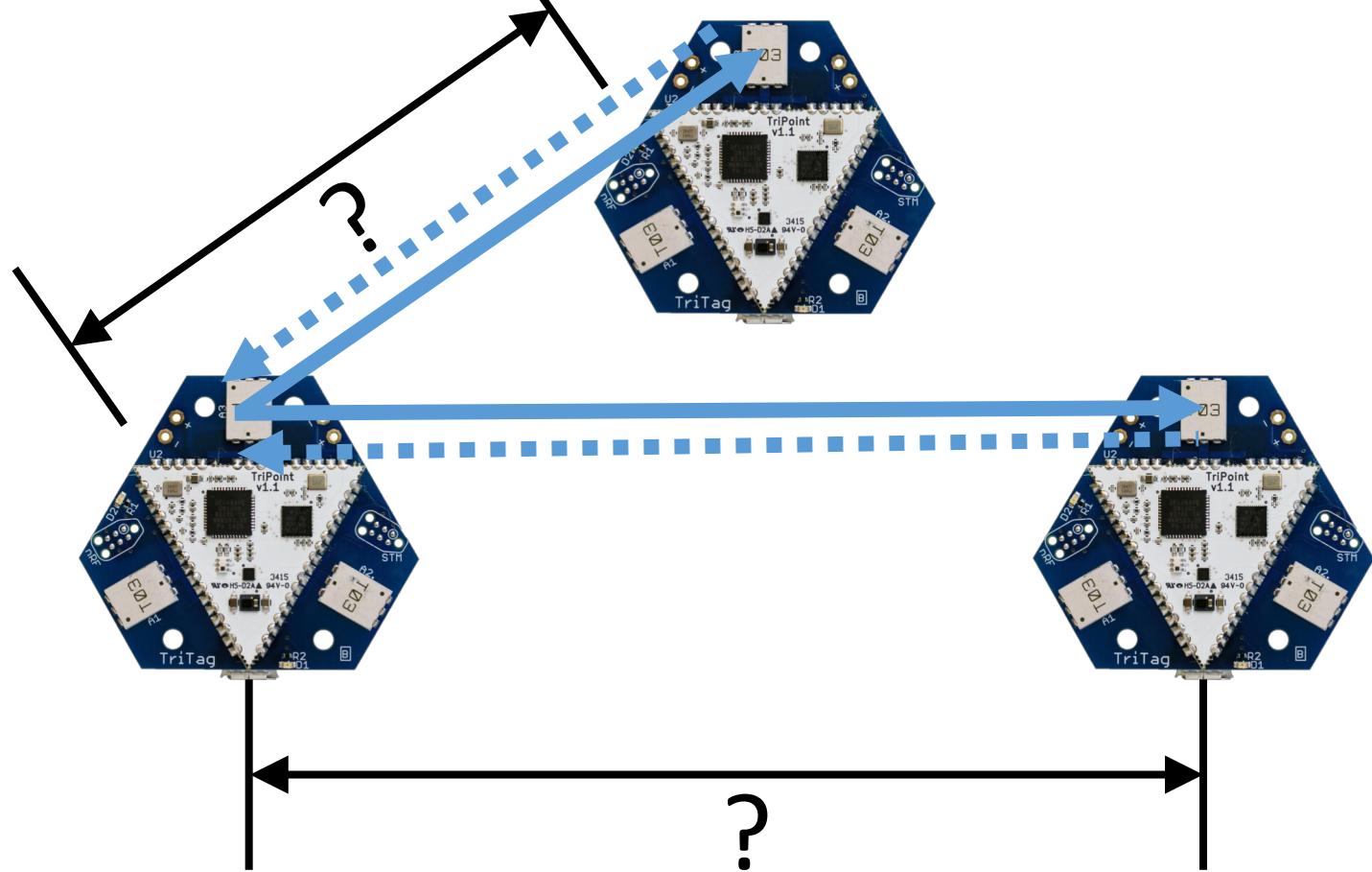
O($2 \cdot N \cdot M$) packets

Example: $2 \cdot 4 \cdot 27 = 216$ packets $\rightarrow 5$ Hz

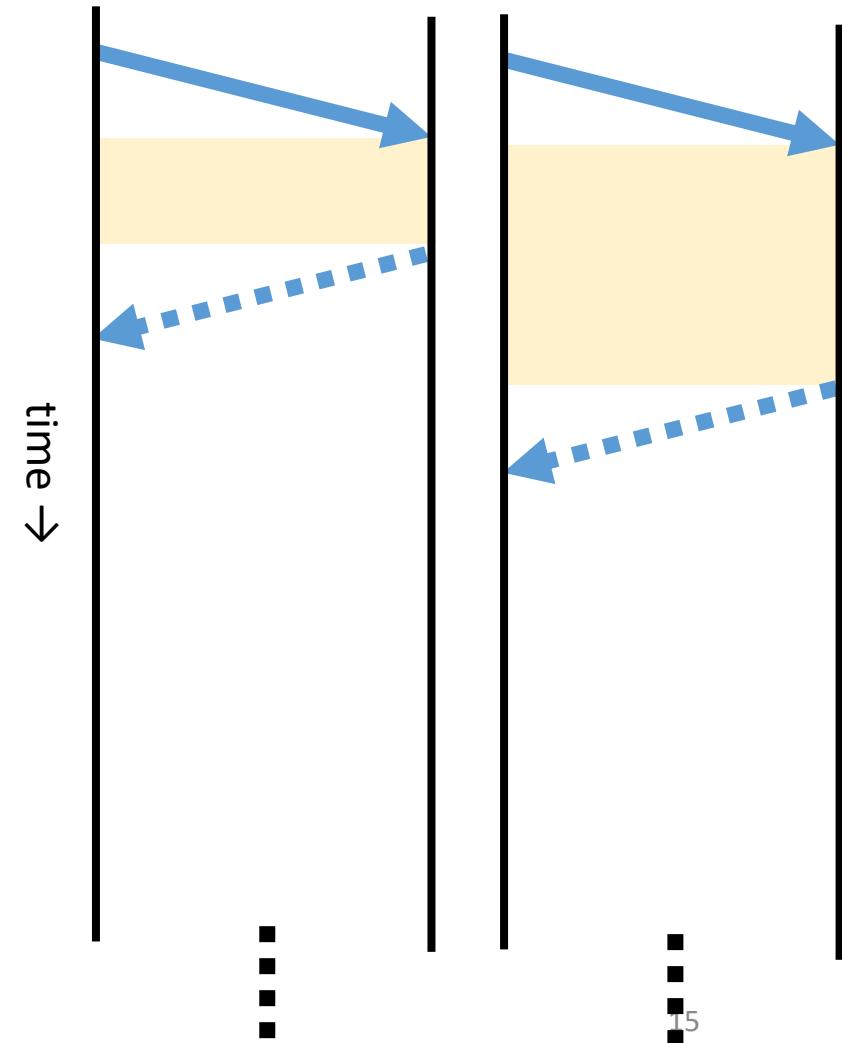
N = # of anchors
M = # of measurements



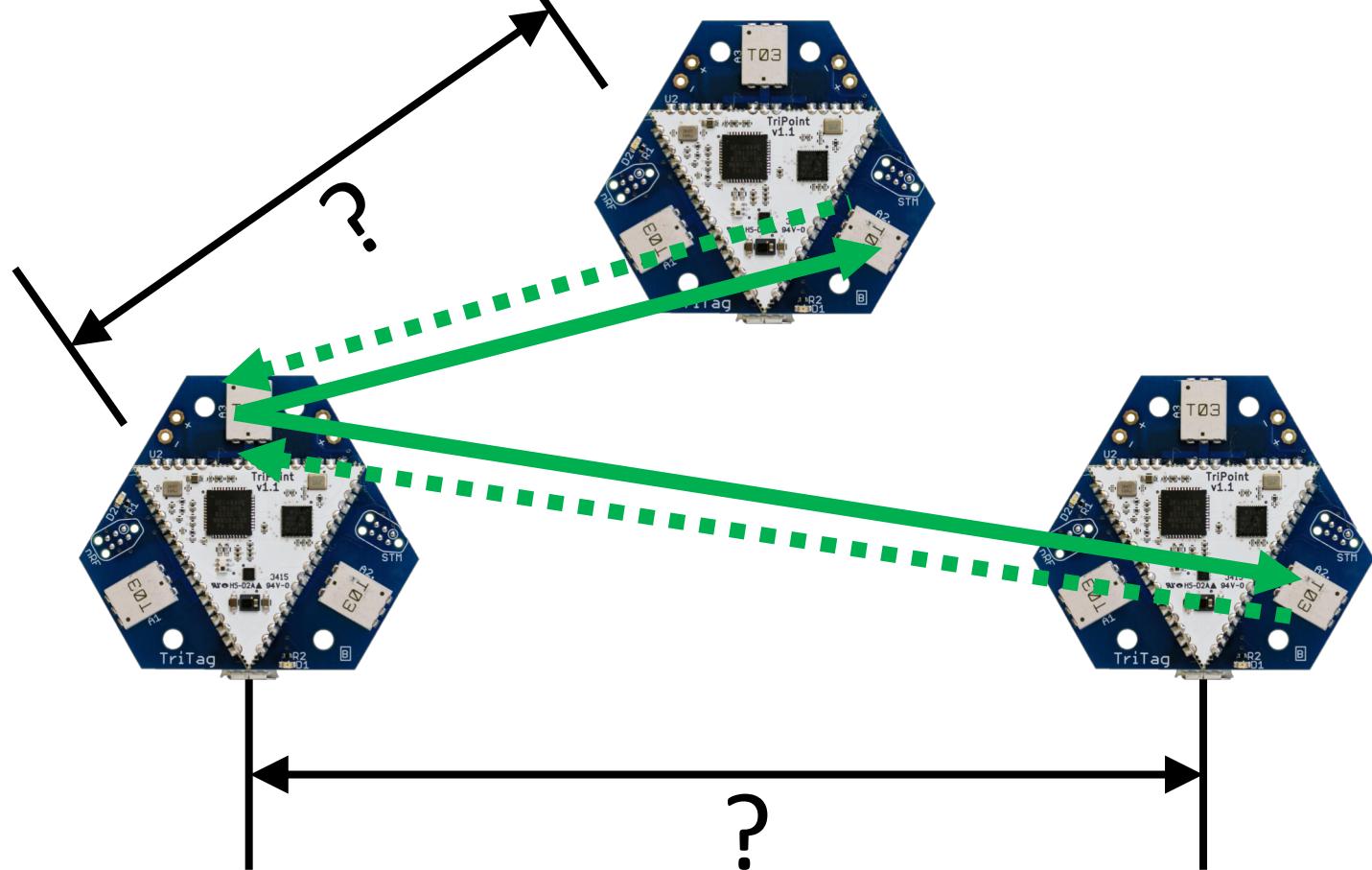
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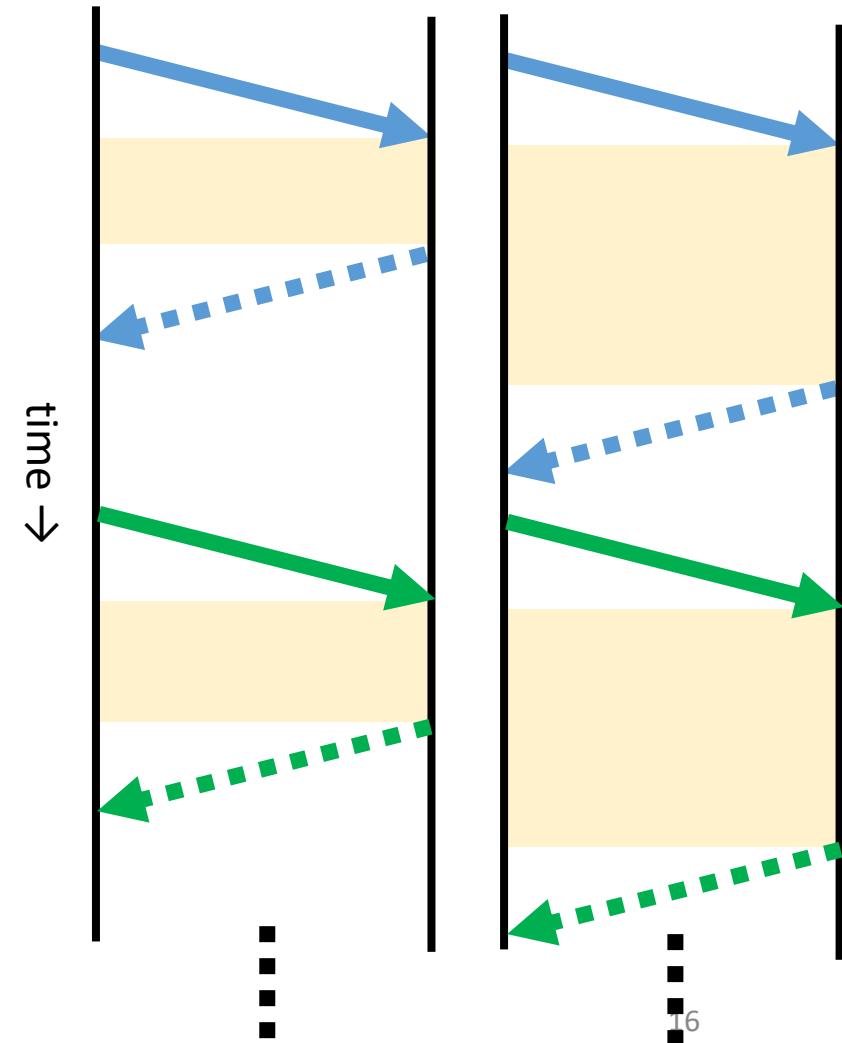
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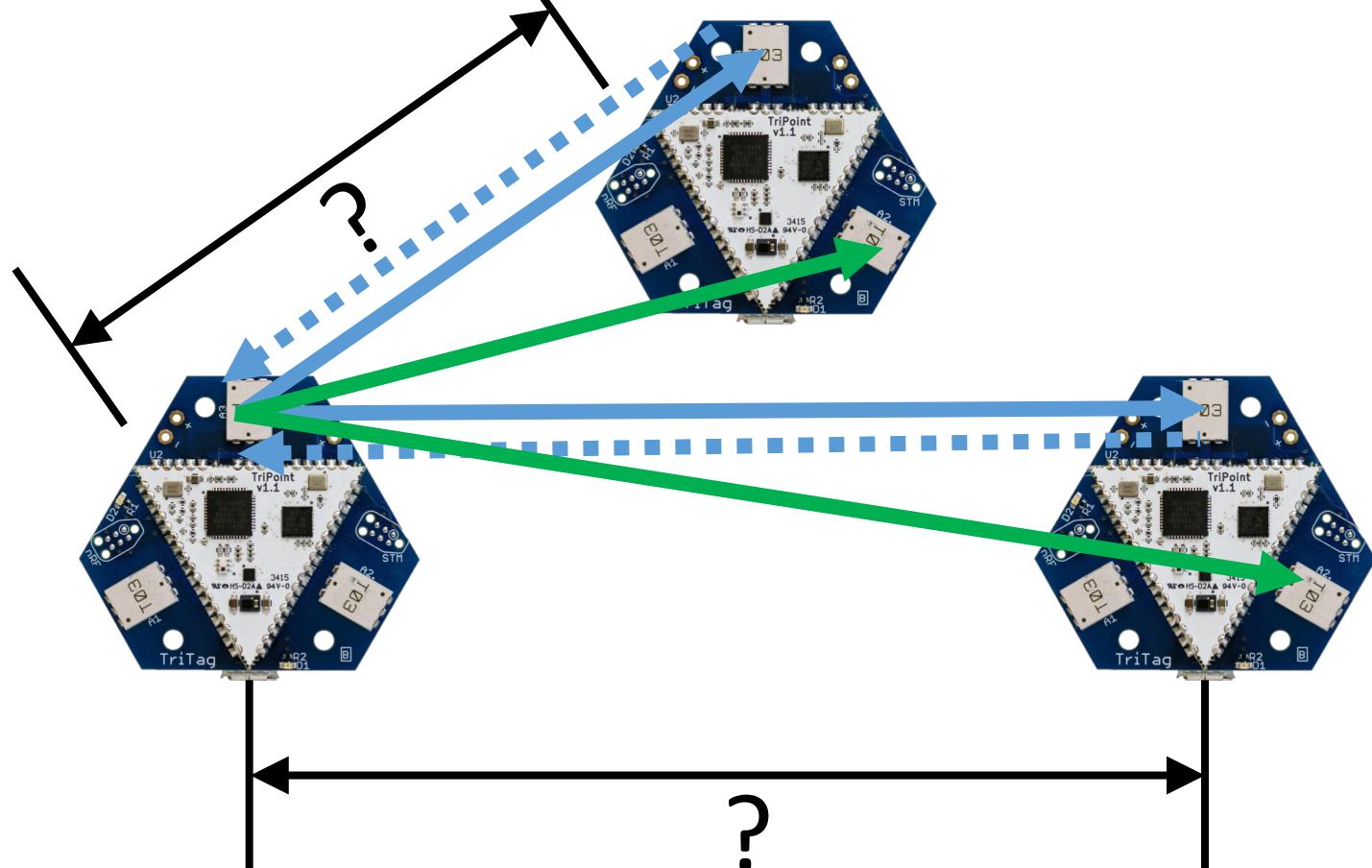
$O((N+1)*M)$ packets

Example: $(4+1)*27 = 135$ packets $\rightarrow 7$ Hz

$N = \# \text{ of anchors}$
 $M = \# \text{ of measurements}$



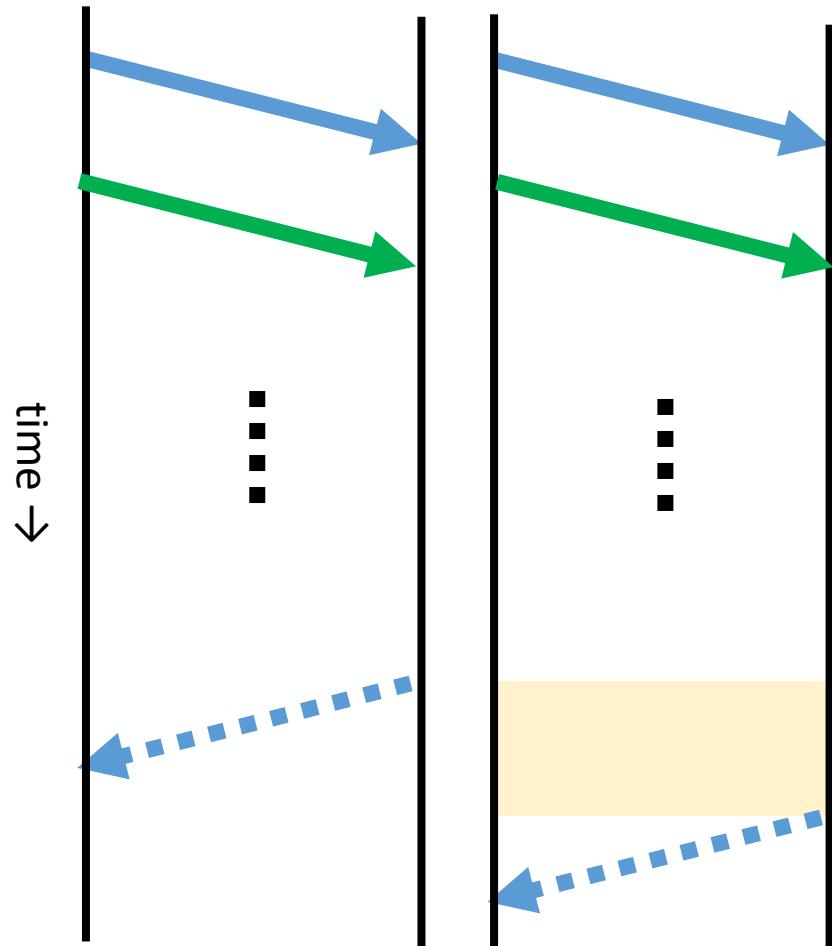
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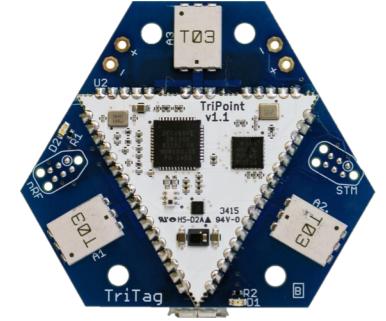
$O(N+M)$ packets

Example: $4+27 = 31$ packets $\rightarrow 32$ Hz

$N = \# \text{ of anchors}$
 $M = \# \text{ of measurements}$



UWB: A Performant Technology with Significant Limitations



- Robustness



SurePoint

- Antenna Diversity

- Regulatory-limited Transmit Power



- Ultra-Wideband Flooding

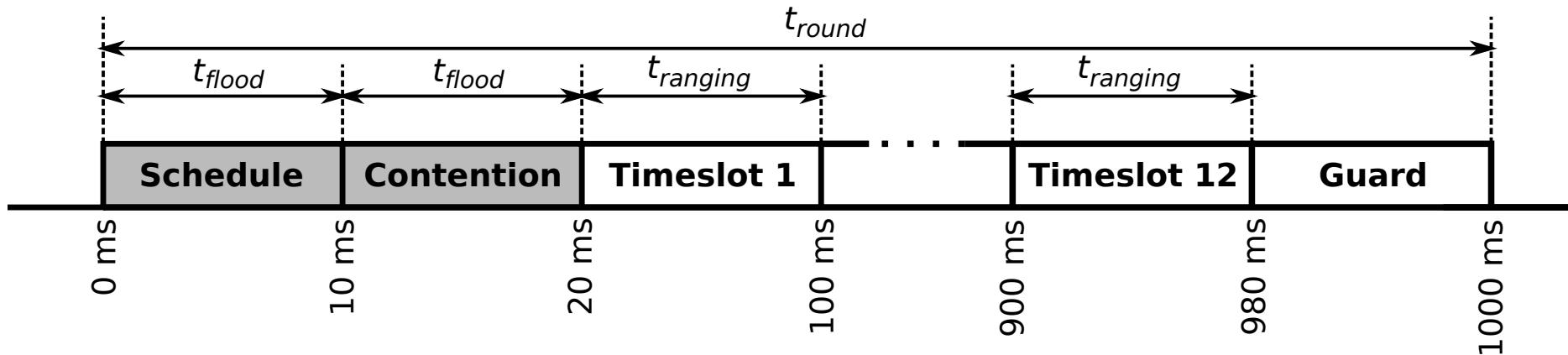
- Scalability



- Lightweight Scheduling & Synchronization

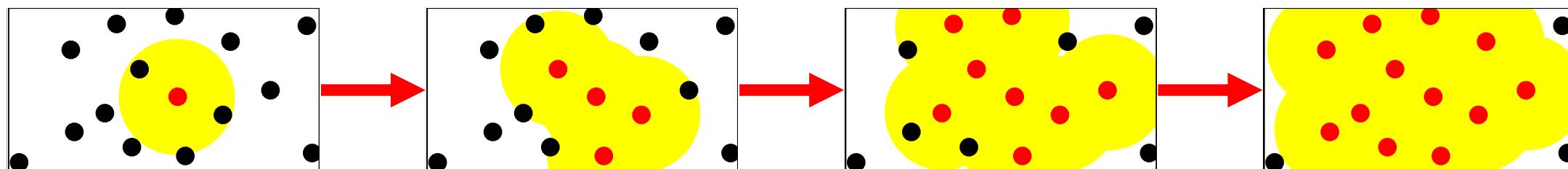
Addressing Scalability: Scheduling and Network Messaging with Glossy Floods

- Adopted Low-Power Wireless Bus (LWB):
 - All data communicated using Glossy floods
 - Host schedules time slots for localization and flooding intervals
 - Incoming tags request to be scheduled during a ‘contention’ period
 - Outgoing tags either request to be unassigned or time out
 - Steady state operation: All tags scheduled with an even assignment of timeslots to tags

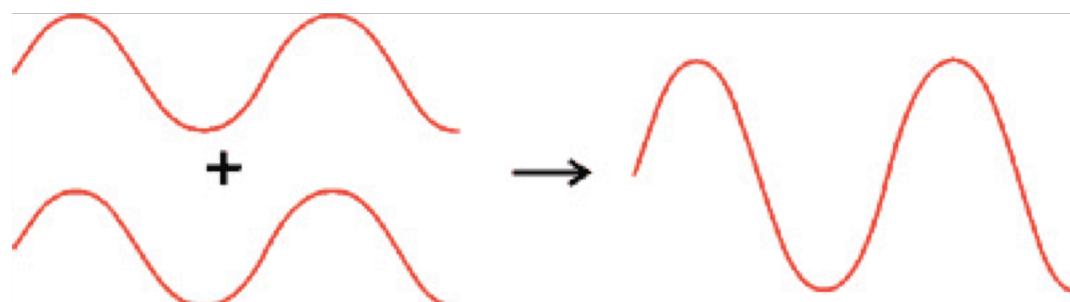


Adopting Glossy Concepts for Network Flooding and Time Synchronization

- Glossy: Flooding with constructive narrowband interference
 - Allows for a robust means of broadcasting a single message to all nodes in the network



Narrowband

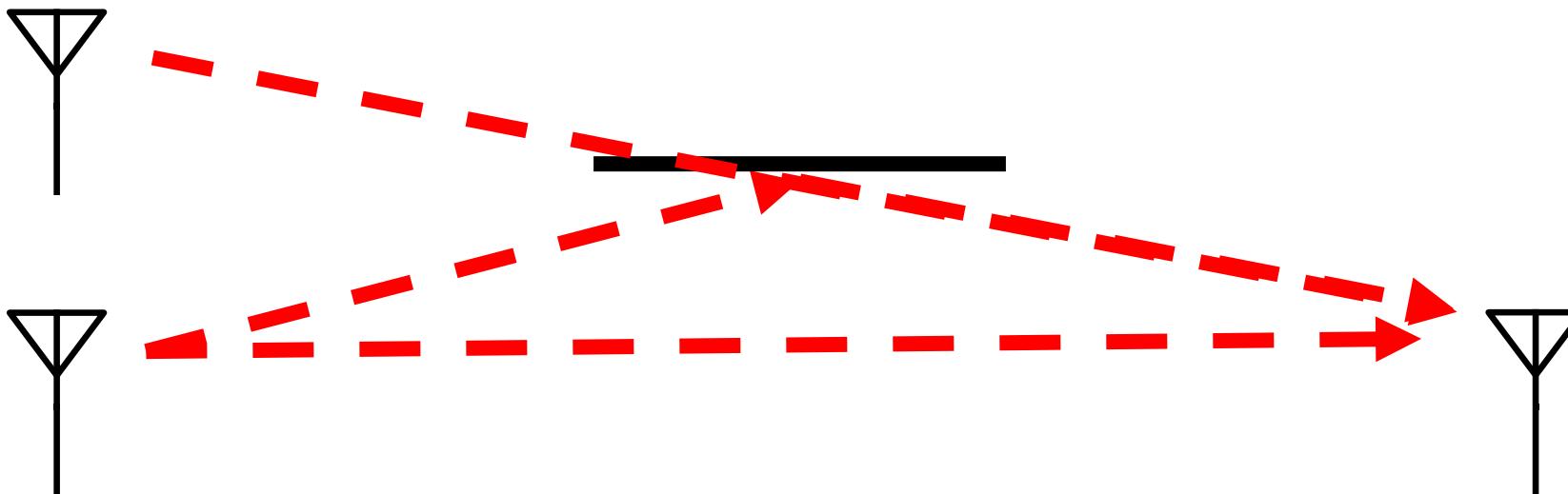
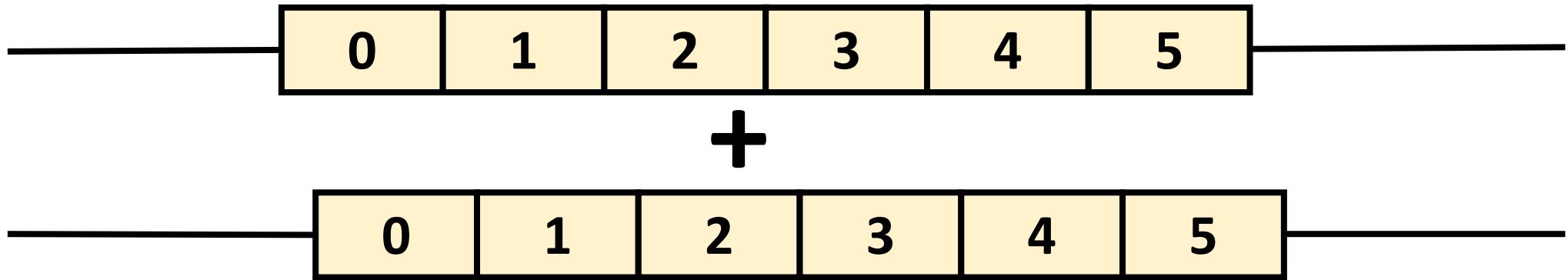


UWB

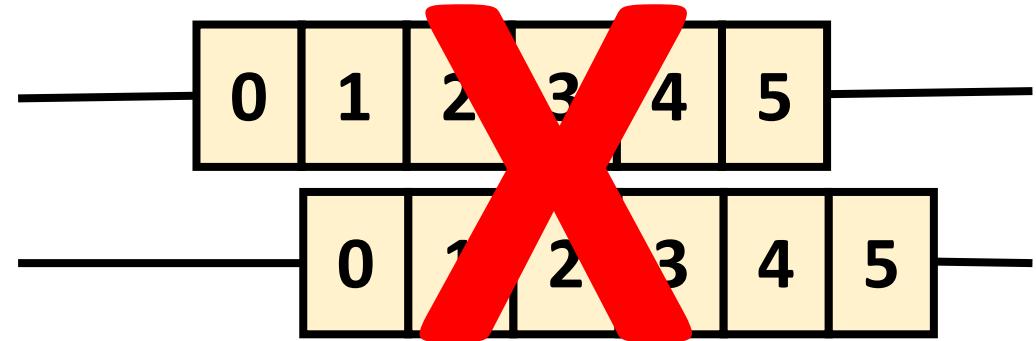


Extending Flooding to UWB:

Multipath = Constructive Interference



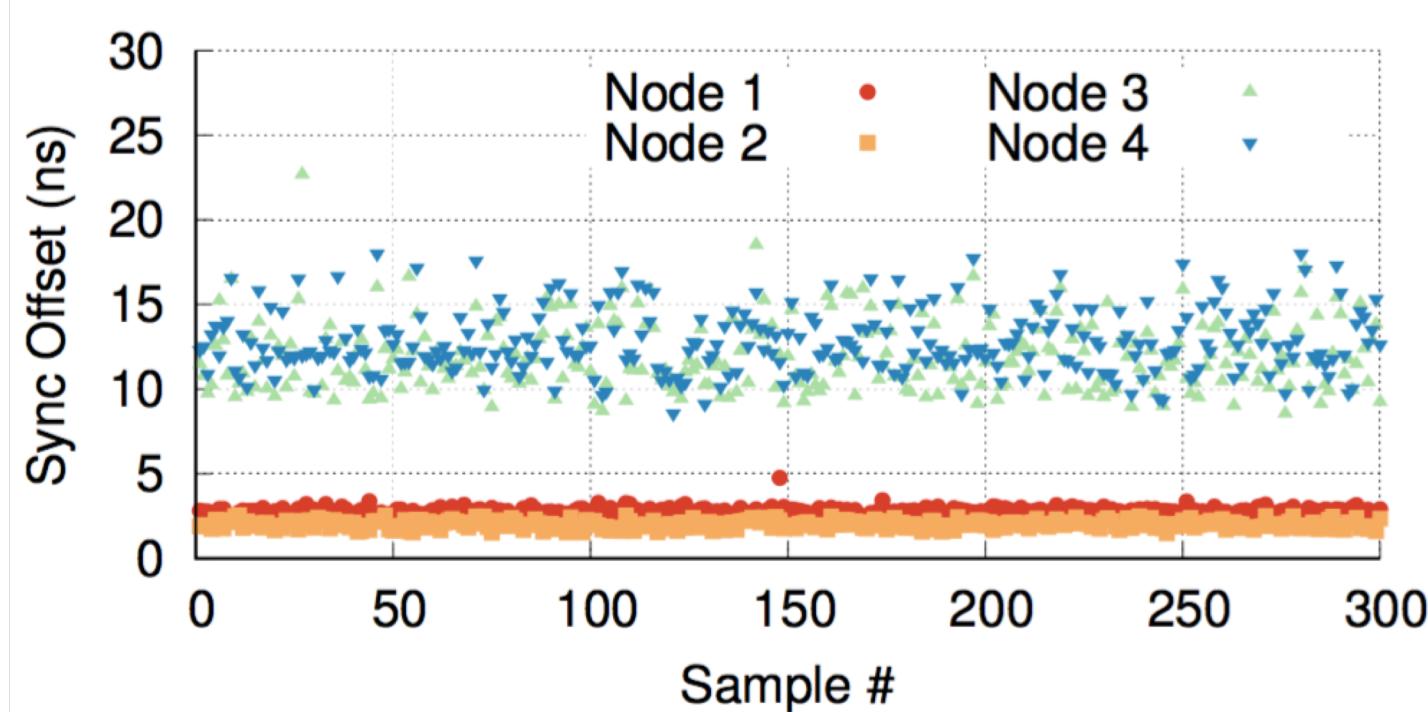
UWB Flooding Condition: Time Synchronization



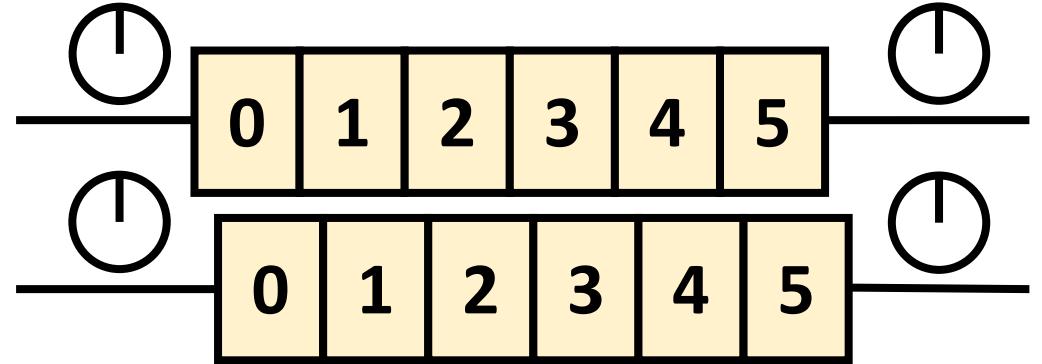
Necessary condition:

Transmitter synchronization must be better than symbol time (preamble: 1 µs, data: 128 ns)

How it's done:
Recurring flooding
transmission times
based on received
flood timestamp



UWB Flooding Condition: Carrier Synchronization



Necessary condition:

*Transmitter carriers must maintain coherence
during flood packet transmission*

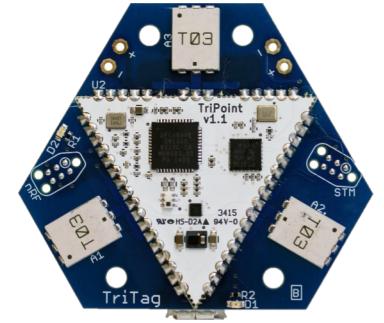
How it's done:

*Crystal tuning continuously adapted
based on inter-sync interval*

UWB: A Performant Technology with Significant Limitations

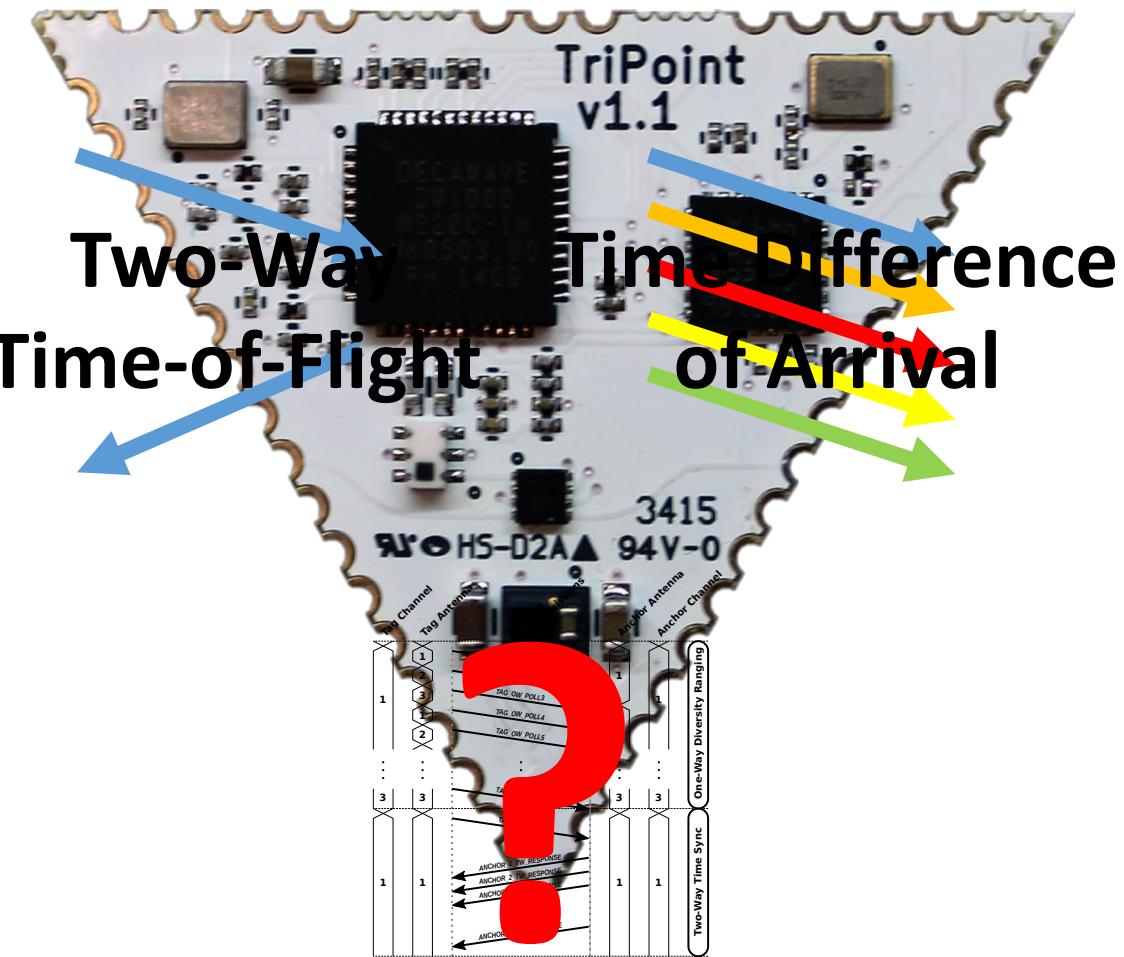
- Robustness
- Regulatory-limited Transmit Power
- Scalability
- Modularity

- • Antenna Diversity
- • Ultra-Wideband Flooding
- • Lightweight Scheduling & Synchronization
- • TriPoint Module



SurePoint's TriPoint Module

- Integrated module providing localization abstraction
 - I2C interface
 - STM32 MCU for protocol orchestration
 - DecaWave DW1000 UWB transceiver
 - Calculates ToAs of incoming packets
- Triangular shape → *Supports antenna diversity*





Conclusion

- Overcoming shortfalls of UWB localization to make deployable systems targeting a wide spectrum of potential applications
- SurePoint:
 - Decimeter-level localization accuracy
 - Worst-case performance enhanced with diversity
 - Network-wide communication, scheduling, and synchronization
 - Scheduling with UWB flooding for reliable, network-wide communication
 - Localization abstraction, modular architecture to ease adoption
 - Performance to enable a variety of localization applications
 - 17 cm median 3D error
 - 95% within 76 cm



Ben Kempke



Questions?

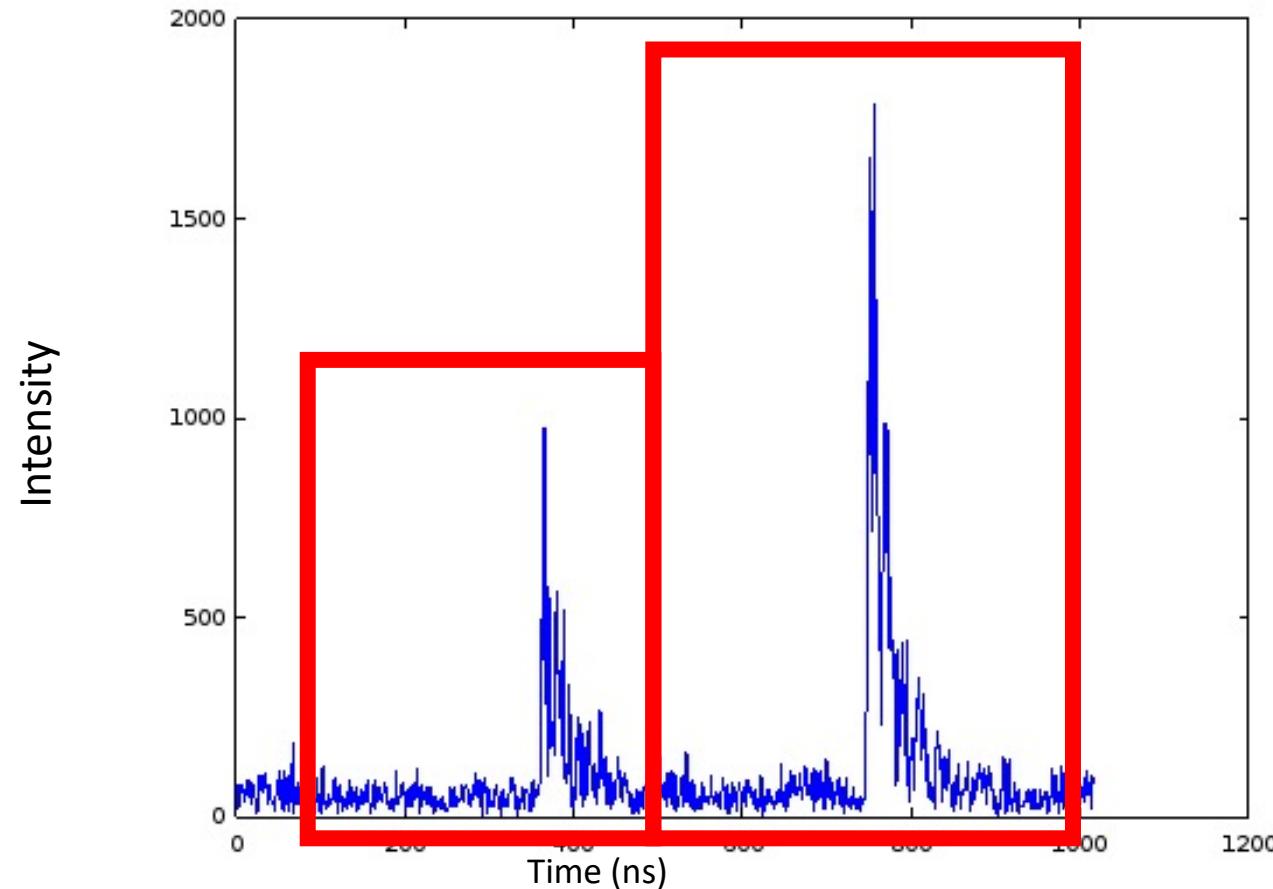


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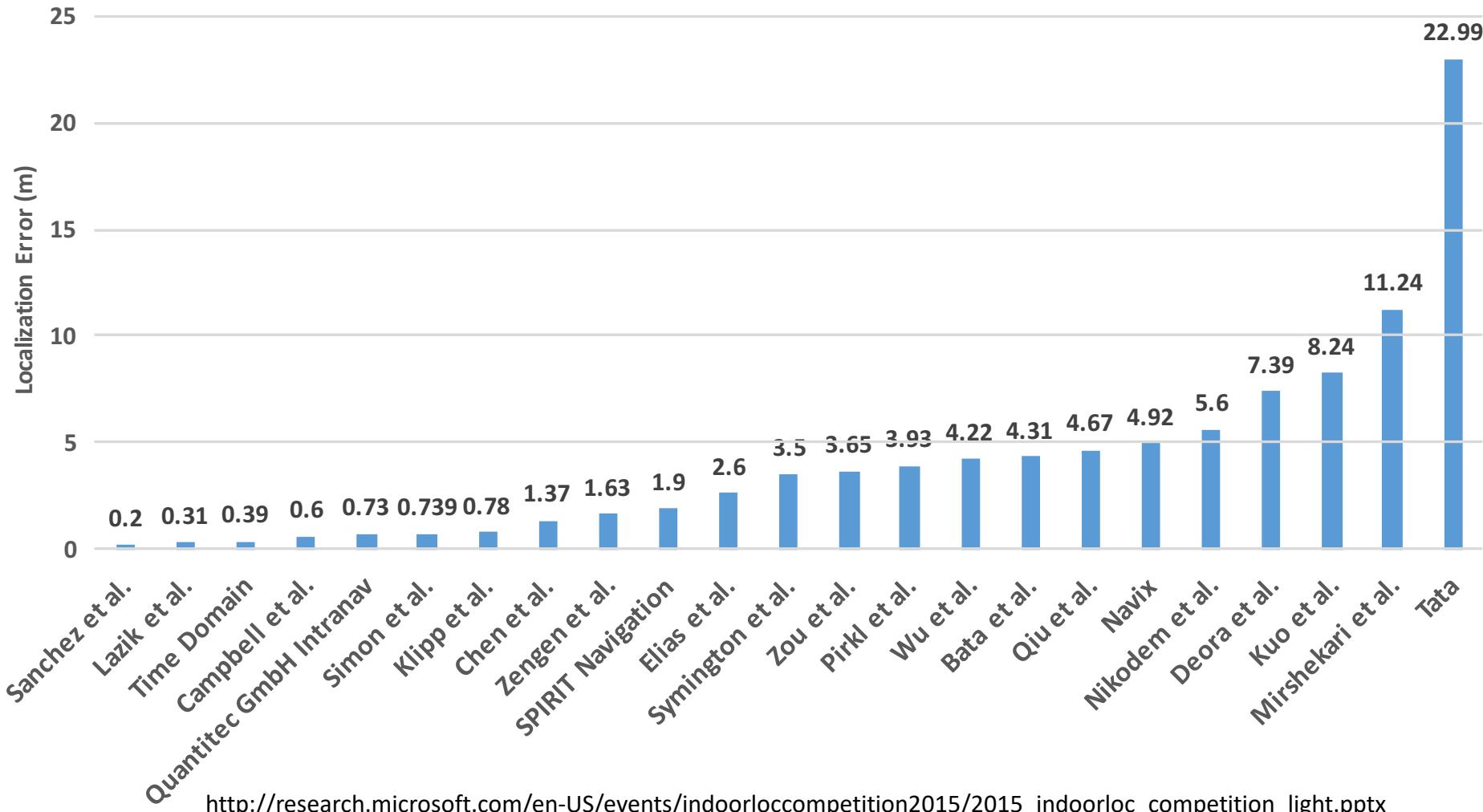


Backup Slides

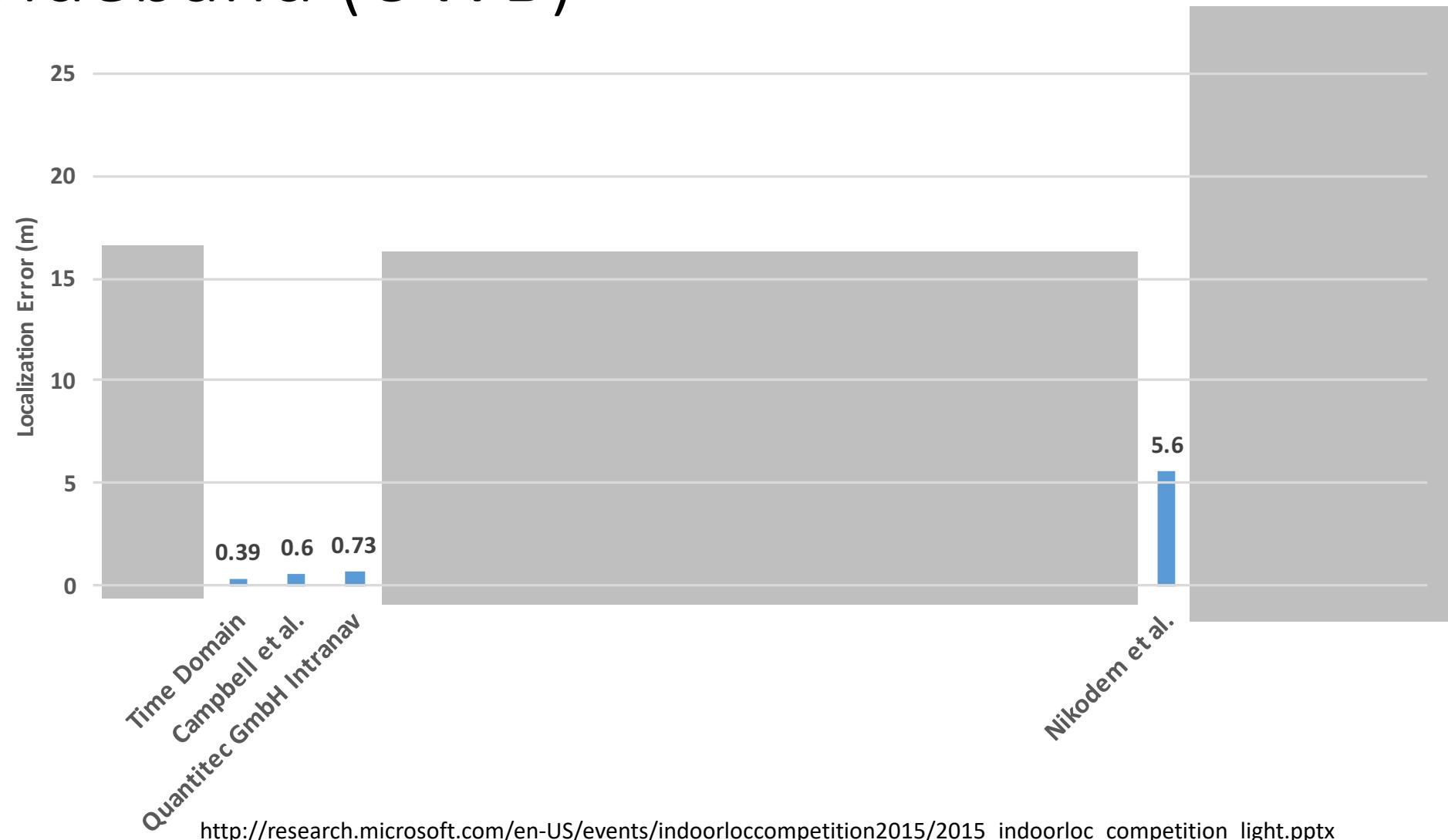
Extending Flooding to UWB: CIR Superposition = Constructive Interference



IPSN'15 Microsoft Indoor Localization Competition: A strong indicator of localization performance

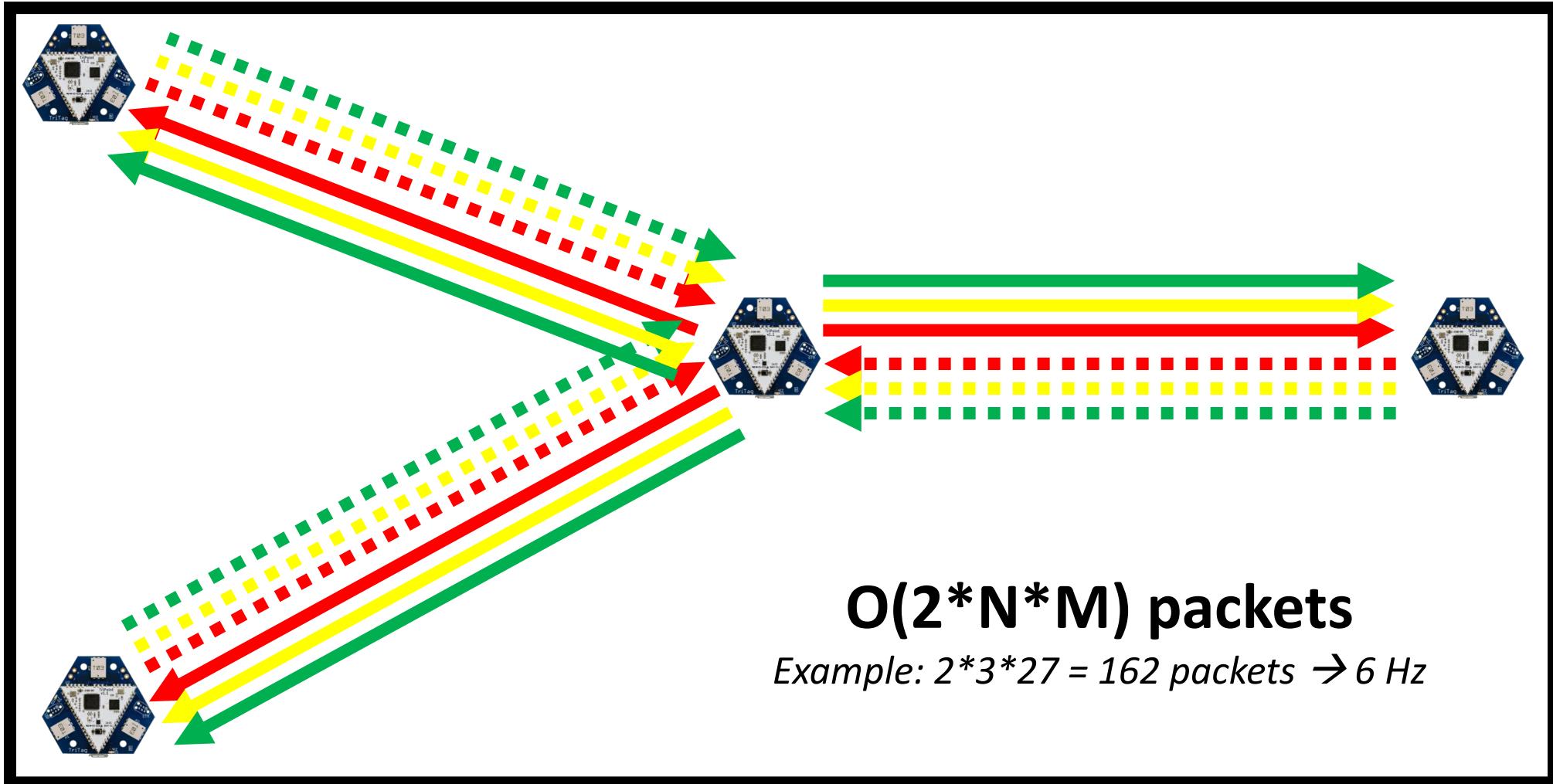


And the best RF-based systems use Ultra-Wideband (UWB)



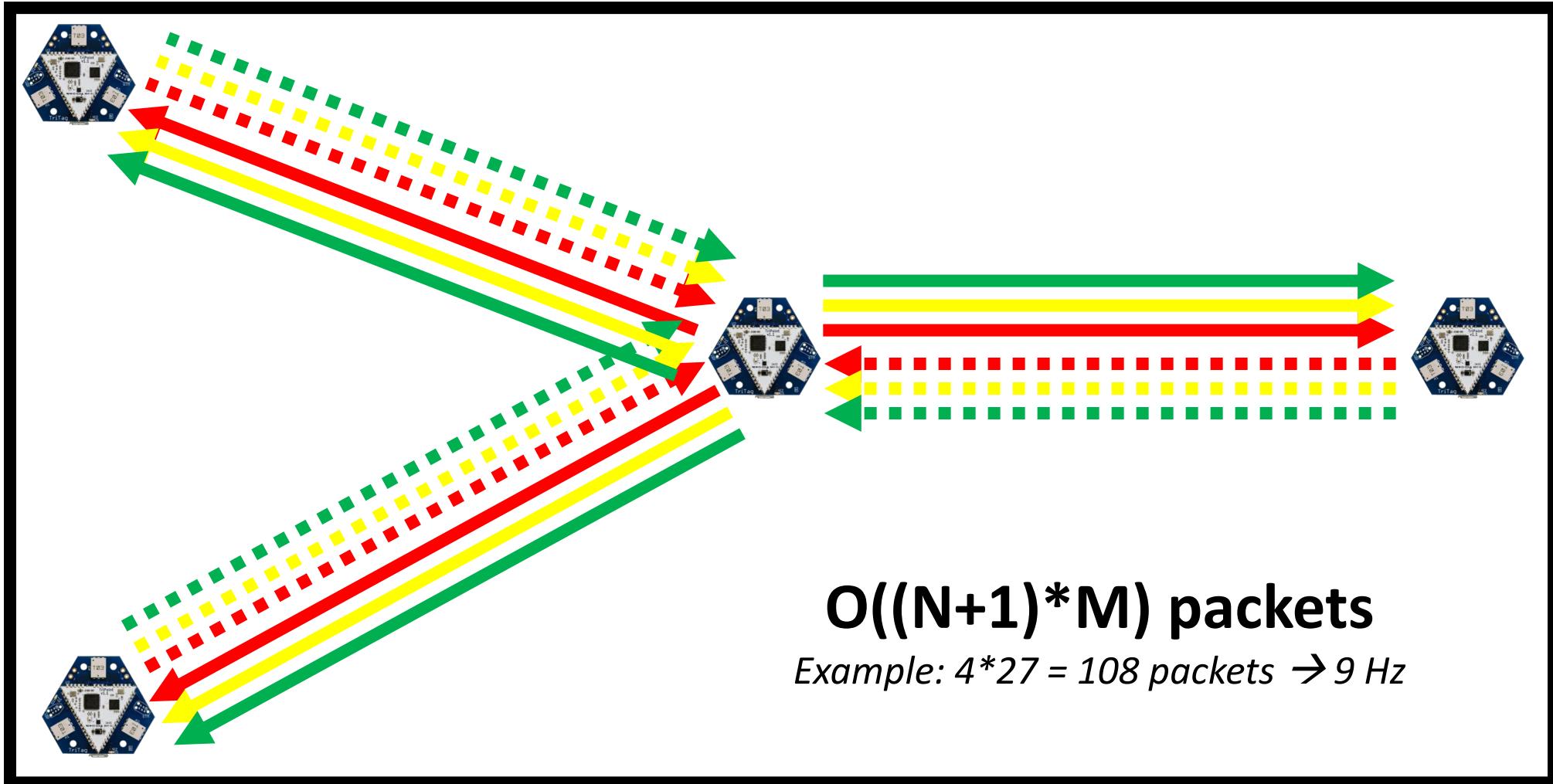
Efficiently Leveraging Diversity

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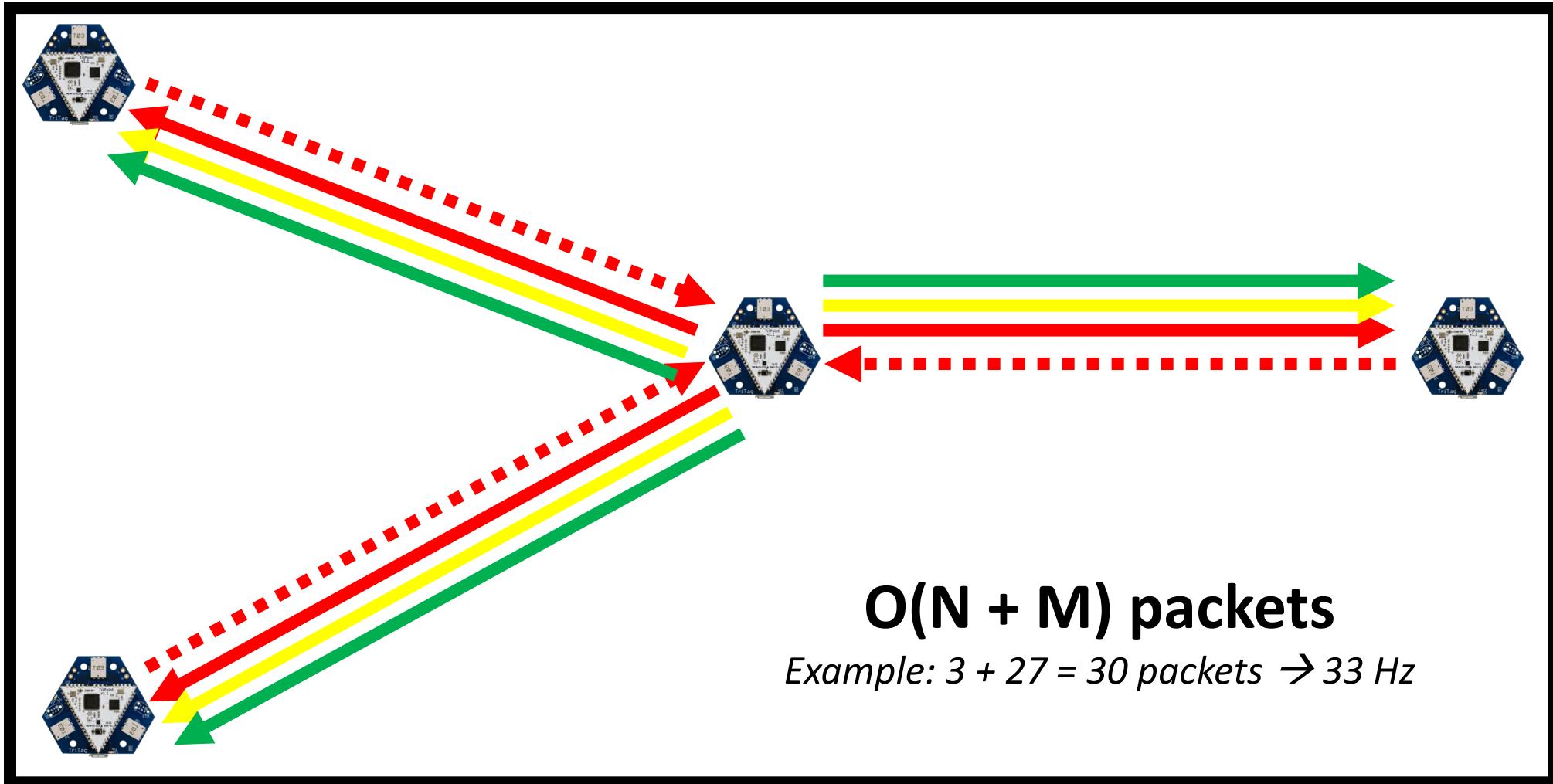
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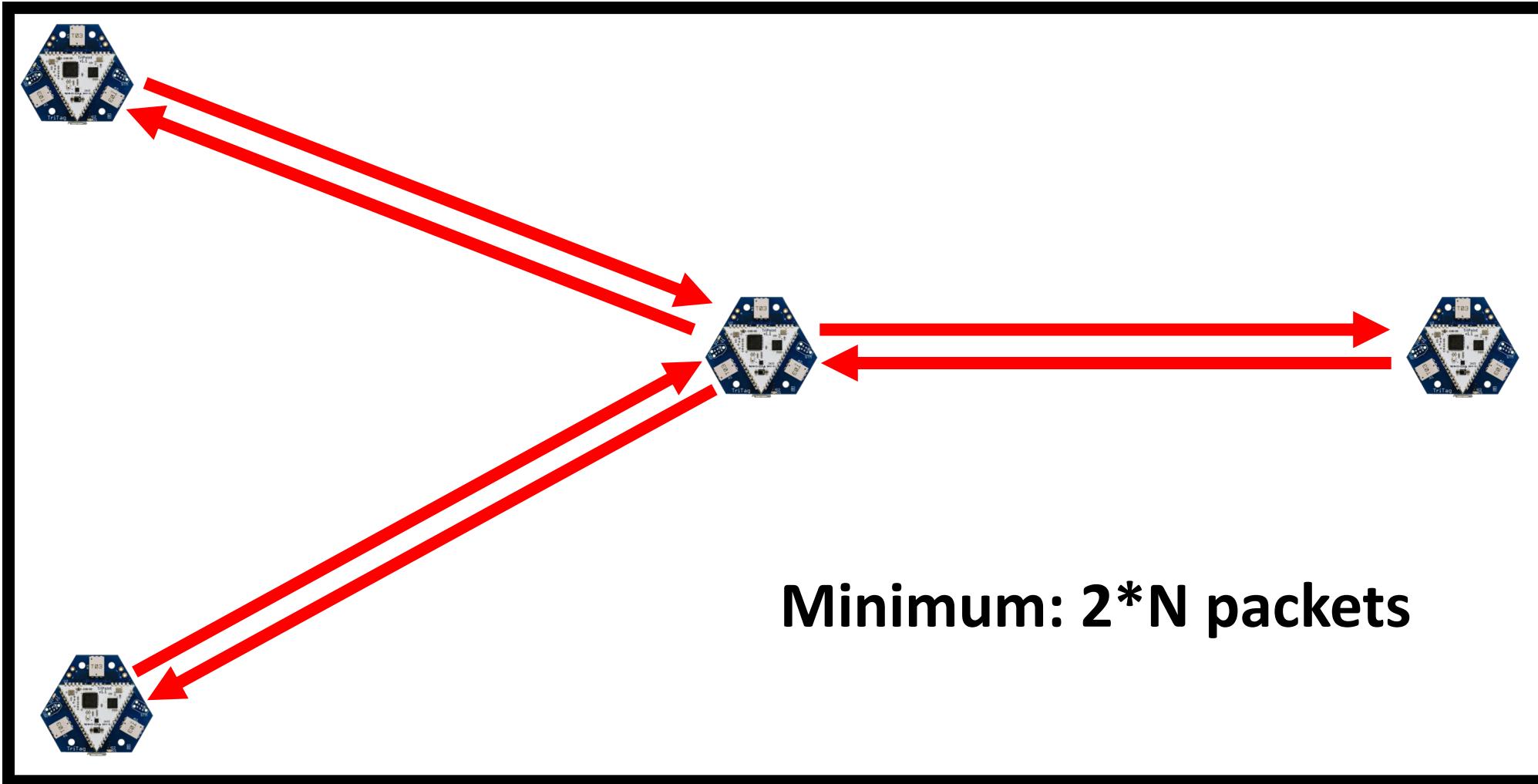
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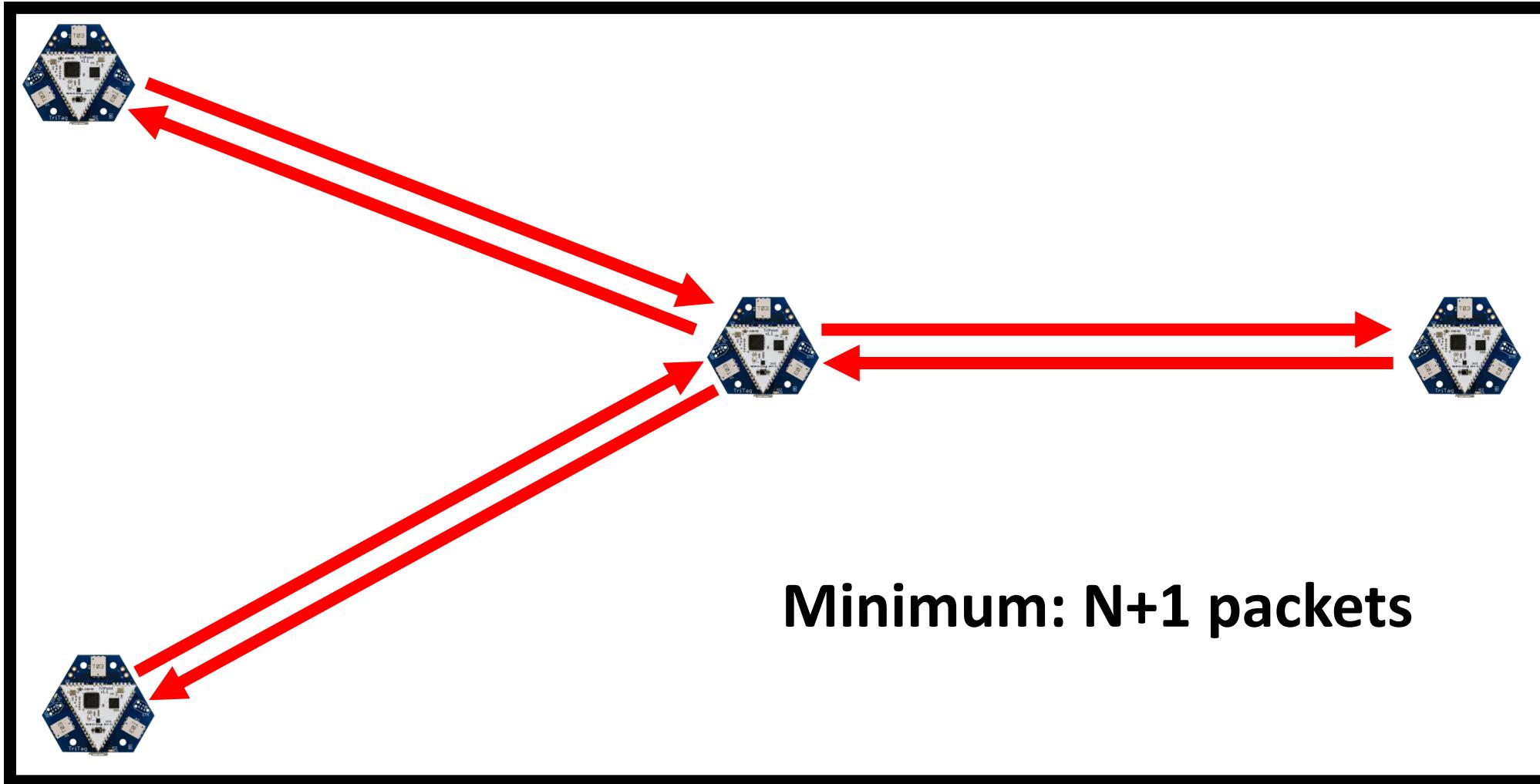
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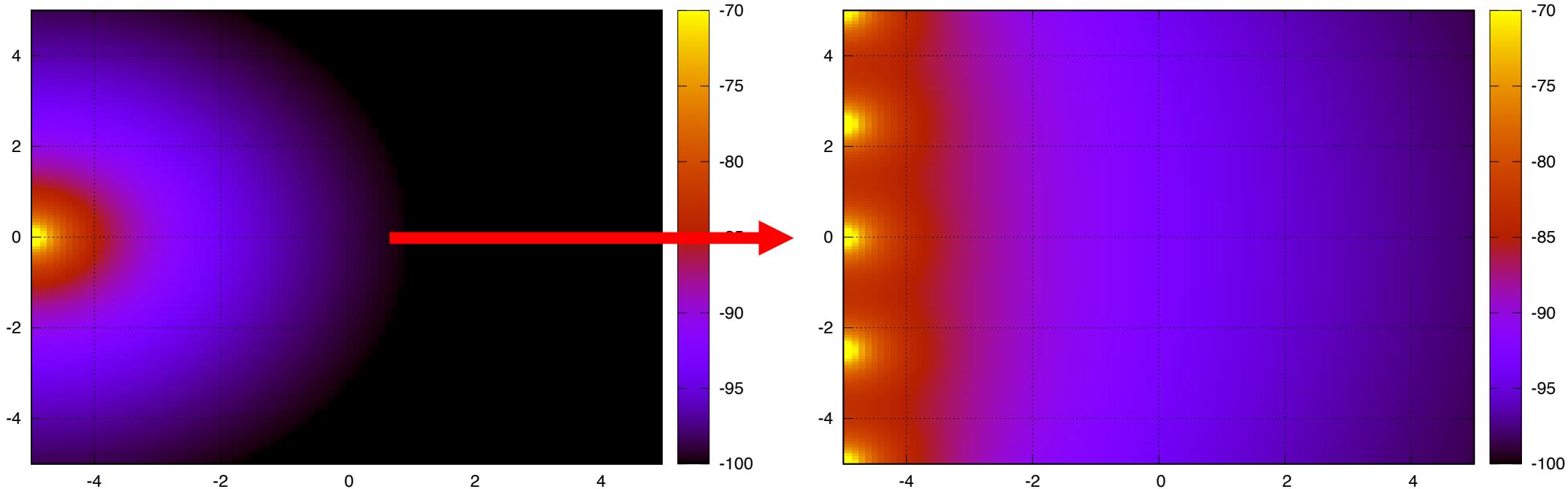


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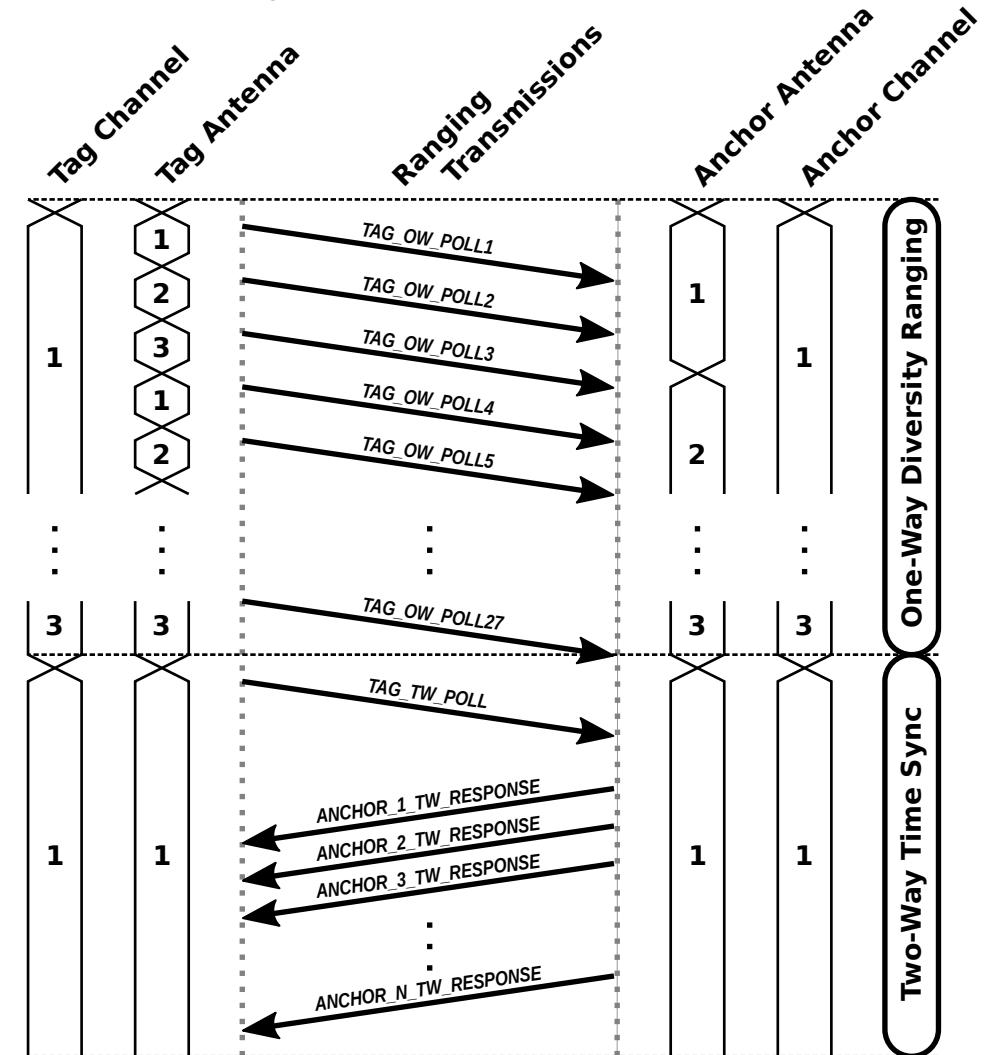


Extending Flooding to UWB: Further Reach with Simultaneous Transmissions

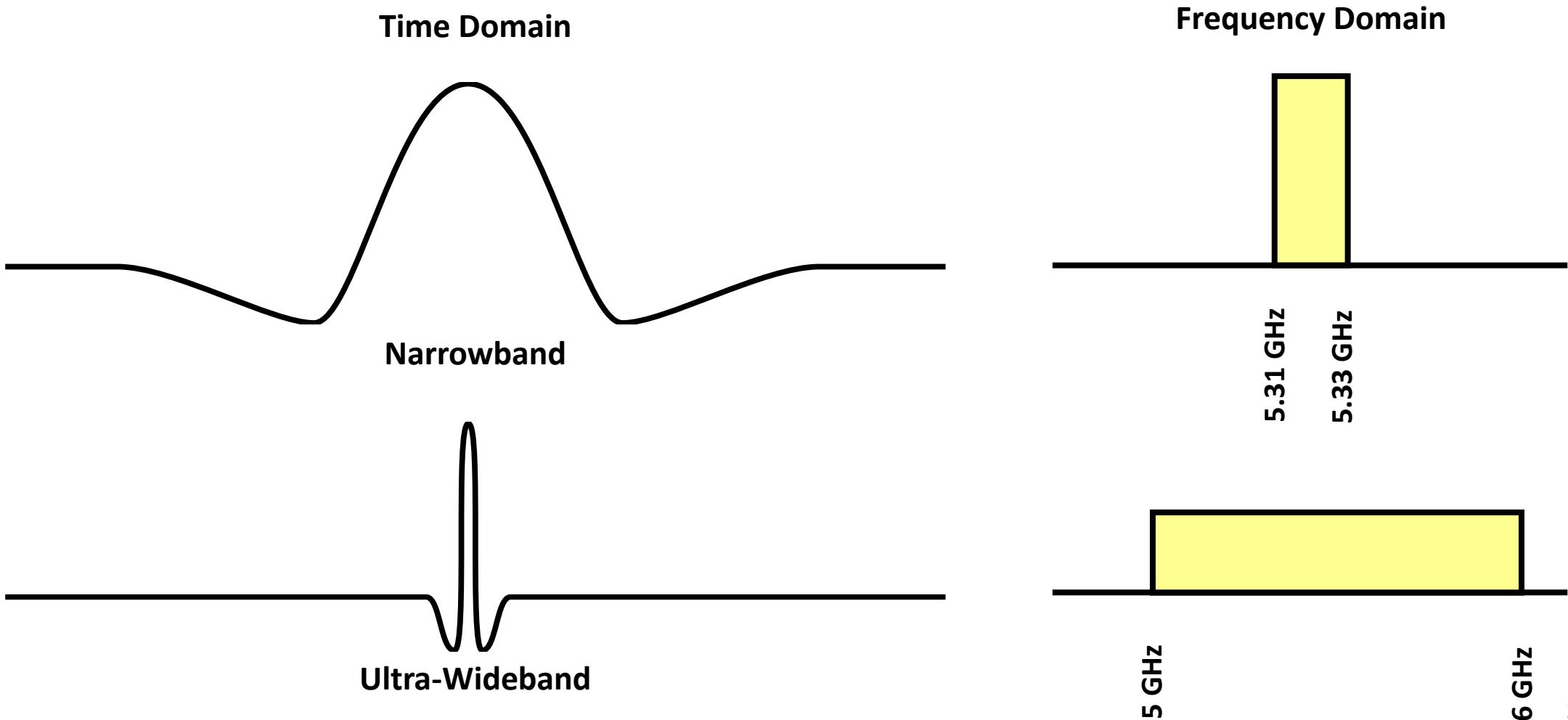


Efficiently Leveraging Diversity

- A total of 27 different combinations:
 - tag antenna (3)
 - anchor antenna (3)
 - UWB channels (3)
- Full 2-way message exchange is too costly ($27 * 4 * 2 = 216$ packets)
- Modified ranging protocol pares this down to a total of 34 required packets
 - 27 *broadcast* one-way ranging packets
 - N (>4) *unicast* anchor → tag packets



Ultra-Wideband (UWB): The Burgeoning Choice for Indoor Localization



SurePoint Performance Assessment

- 17 cm median 3D error
- 95% of estimates within 76 cm
- No noticeable degradation in the presence of fast tag movement (2.4 m/s)
- <1 Watt active power

