Synchronous Packet Transmissions Enable Simple Yet Accurate Protocol Modeling

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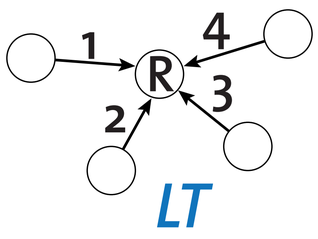
Motivation

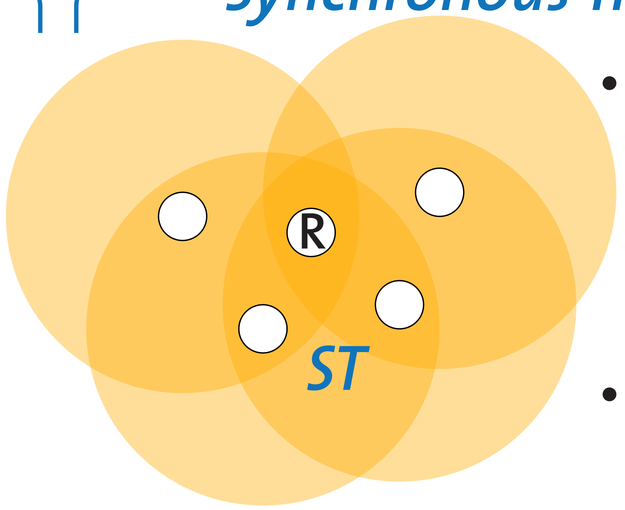
Traditional multi-hop low-power wireless protocols are intricate and difficult to model

- Protocols maintain substantial **network state** (*e.g.*, link quality estimates, packet queue lengths)
- Nodes update their local state **concurrently** and in an **uncoordinated** fashion against unpredictable topology dynamics



Protocol modeling often stops at the link layer, achieving model errors of 2-7% [Zimmerling et al., IPSN'12]

Synchronous Transmissions (ST)



- Capture effect and constructive interference boost the one-hop packet reliability of ST over link-based transmissions (LT)
- ST enable efficient multi-hop protocols with very little network state

Do ST also simplify accurate modeling of ST-based protocols?

Bernoulli Assumption in Low-Power Wireless

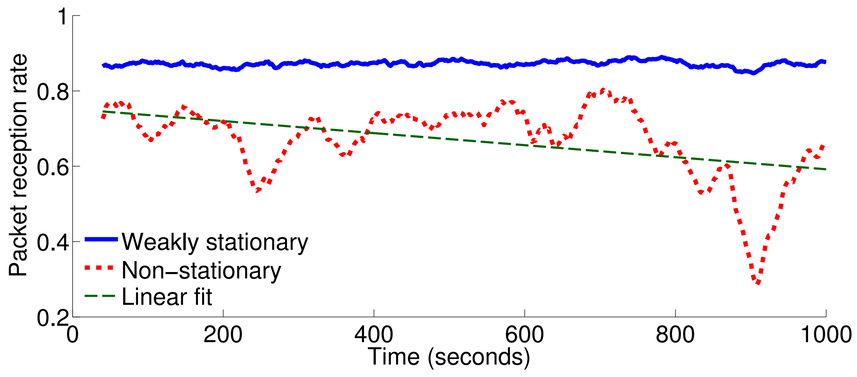
Common assumption: packet receptions/losses at a receiver adhere to a sequence of i.i.d. Bernoulli trials

Methodology

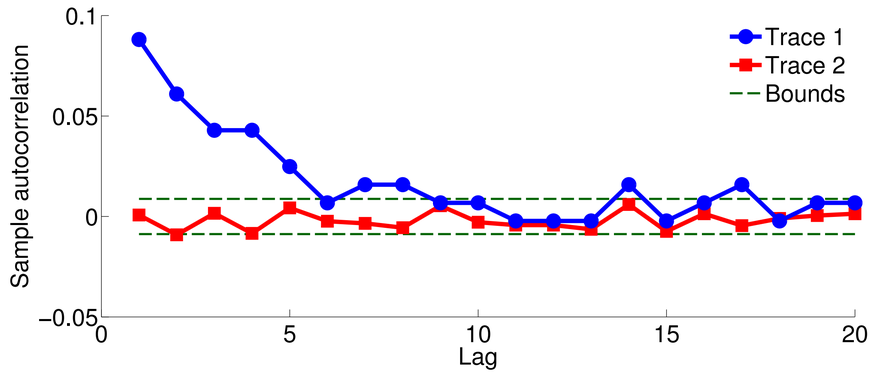
Experiments on the **Indryia** testbed *(139 TelosB nodes, 20-byte packets, 20 ms inter-packet interval (IPI), 0 and -15 dBm Tx power)*

- **ST-Type**: 70 random nodes, one at a time, initiate 50,000 Glossy floods [Ferrari et al., IPSN 11]
- **LT-Type**: all 139 nodes, one at a time, broadcast 50,000 packets

Collected >1,200,000,000 packet reception events



Represent packet reception traces as **binary time series** and filter out non-weakly stationary traces

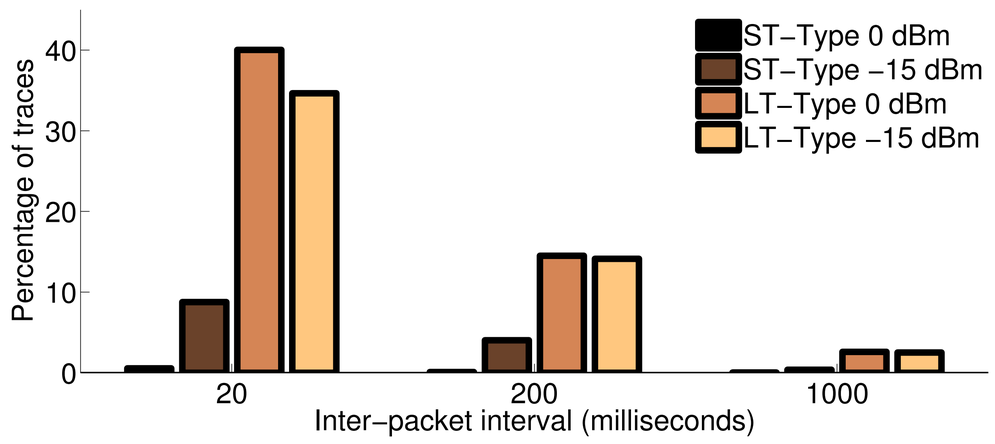


Bernoulli assumption holds if the **sample auto-correlation** at lag 1 lies within specific bounds

Key Finding

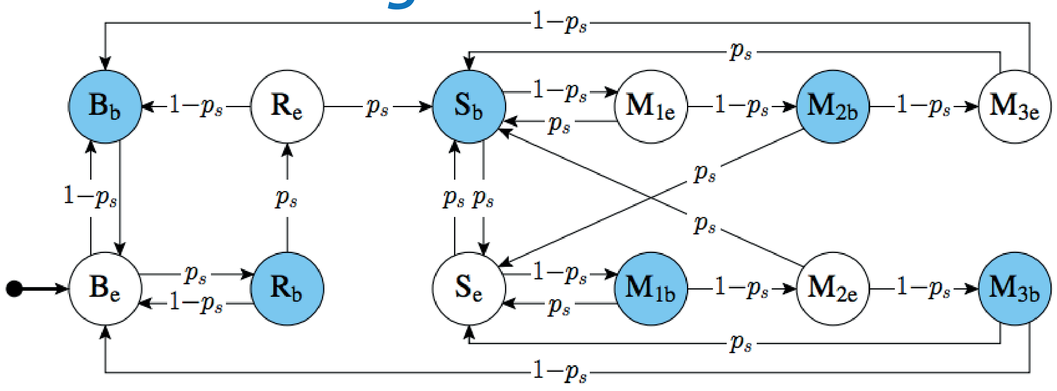
The Bernoulli assumption is significantly more valid to ST in Glossy than to LT

At 0 dBm transmit power, the Bernoulli assumption holds for 99.5% of the ST-Type traces, whereas it holds only for 60% of the LT-Type traces at the smallest IPI

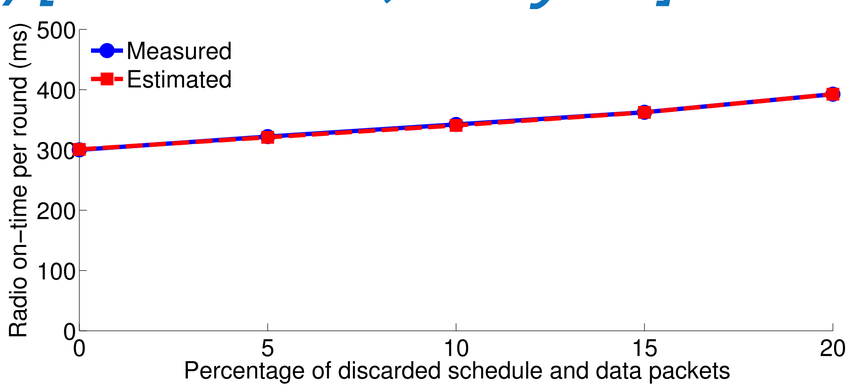


Percentage of traces for which the Bernoulli assumption does NOT hold

Modeling the Low-Power Wireless Bus (LWB) [Ferrari et al., SenSys 12]



The validity of the Bernoulli assumption to ST in Glossy allows to model the behavior of a LWB node as a DTMC



The relative model error in energy against real measurements is as low as 0.25%

The validity of the Bernoulli assumption to ST enables simple DTMC models with sub-percent model errors

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