



Opening the Sensornet Black Box

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The Sensornet Black Box

- It is difficult to observe what occurs deep within a sensor network
- This is the direct result of energy constraints on a mote.
- This lack of visibility is the principal difficulty in development.

The MNet Architecture

“Minimize the energy cost of diagnosing the cause of a failure or behavior”

Outline

- Survey of Failures
- The MNet Architecture
- A Design Example
- Further Implications

What kinds of failures are observed in real deployments?

- System Interactions: software conflicts
 - *Murphy Loves Potatoes*
 - *Vigilnet*
 - *A Line in the Sand*
 - *Unwired Wine*

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- System Interactions: software conflicts
- Network Problems: Saturation & Congestion
 - *A Line in the Sand*
 - *TASK*
 - *Vigilnet*
 - *Sensorscope*
 - *The Heathland Experiment*
 - *Flush*

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- Protocol Issues: Conflicts & Failures
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What kinds of failures are observed in real deployments?

- System Interactions: software conflicts
- Network Problems: Saturation & Congestion
- Protocol Issues: Conflicts & Failures
- *Unknown*
 - *Unwired Wine*
 - *TASK*
 - *Murphy Loves Potatoes*
 - *The Heathland Experiment*
 - *Monitoring Volcanic Eruptions*
 - *Industrial Sensor Networks*
 - *A Line in the Sand*

Effects of Failures on Deployment Performance



Peter Scott

Great Duck Island: 58%

R. Szewczyk, J. Polastre, A. Mainwaring, and D. Culler. An analysis of a large scale habitat monitoring application. In *Proceedings of the Second ACM Conference On Embedded Networked Sensor Systems (SenSys)*, 2004.

Effects of Failures on Deployment Performance



Great Duck Island: 58%
Redwoods : 40%

G. Tolle, J. Polastre, R. Szewczyk, D. Culler, N. Turner, K. Tu, S. Burgess, T. Dawson, P. Buonadonna, D. Gay, , and W. Hong. A macroscope in the redwoods. In *Proceedings of the Third ACM Conference on Embedded Networked Sensor Systems (SenSys)*, 2005.

Effects of Failures on Deployment Performance



Great Duck Island: 58%
Redwoods : 40%
Potato Field: 2%

K. Langendoen, A. Baggio, and O. Visser. Murphy loves potatoes: Experiences from a pilot sensor network deployment in precision agriculture. In *the Fourteenth Int. Workshop on Parallel and Distributed Real-Time Systems (WPDRTS)*, 2006.

Effects of Failures on Deployment Performance



Great Duck Island: 58%
Redwoods : 40%
Potato Field: 2%
Volcan Reventador: 68%

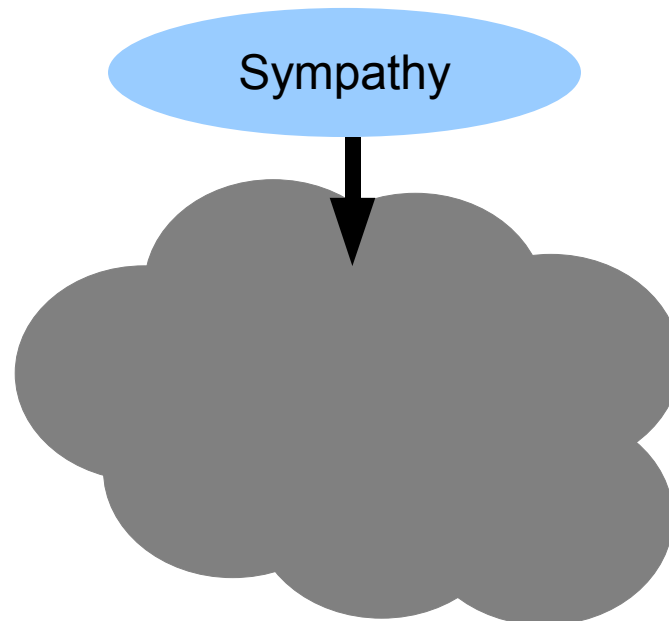
G. Werner-Allen, K. Lorincz, J. Johnson, J. Leess, and M. Welsh. Monitoring volcanic eruptions with a wireless sensor network. In *Proceedings of the Second European Workshop on Wireless Sensor Networks (EWSN)*, 2005.

Management and Debugging

- Sympathy
- Lightweight RPC
- Network Snooping Tools

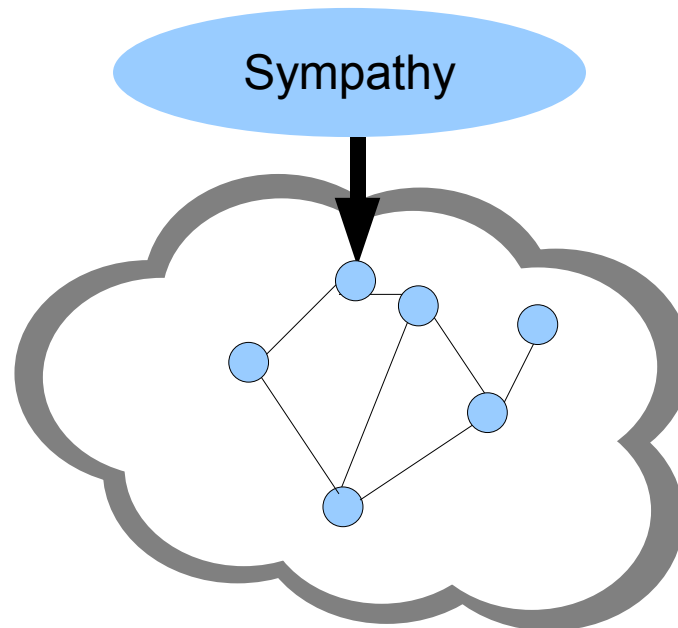
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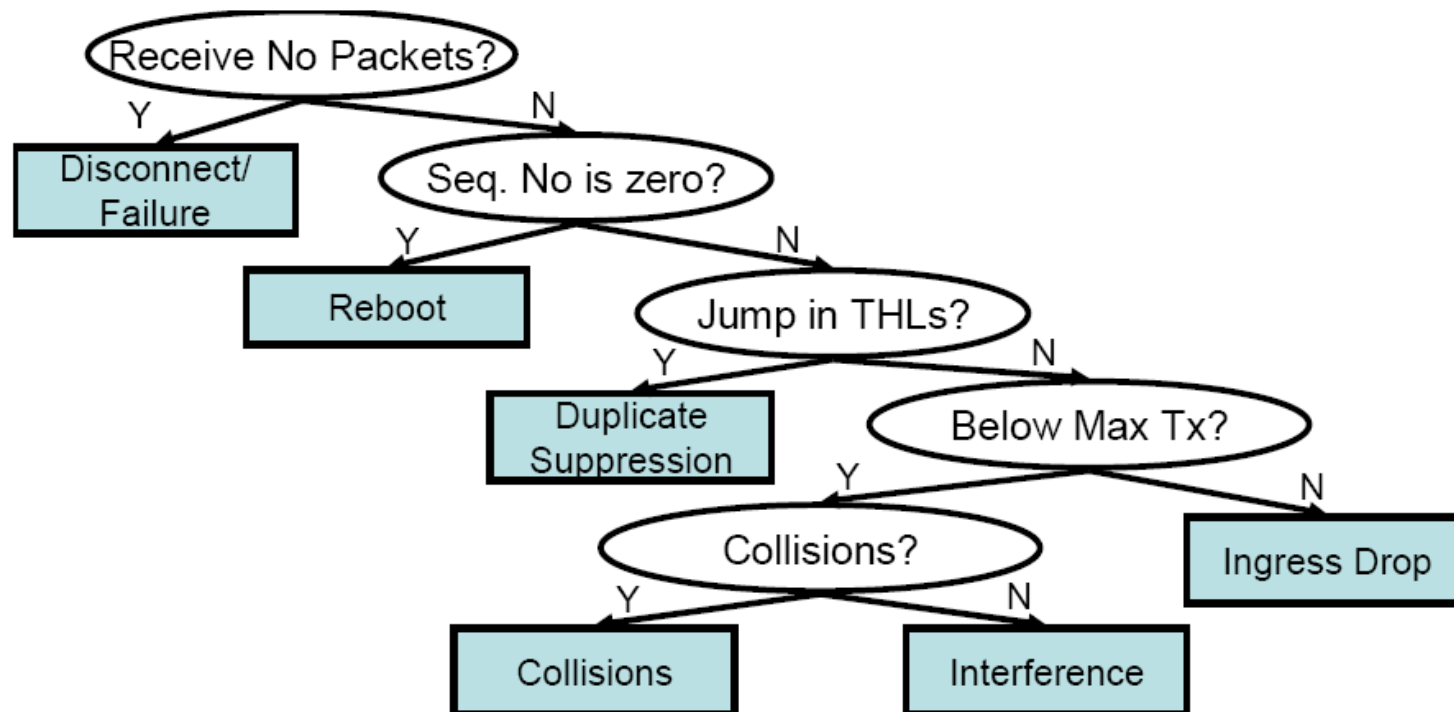


Outline

- Survey of Failures
- ***The MNet Architecture***
- A Design Example
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Visibility Metric

“Minimize the energy cost of diagnosing the cause of a failure or behavior”



The Need For Isolation

Isolation simplifies reasoning.

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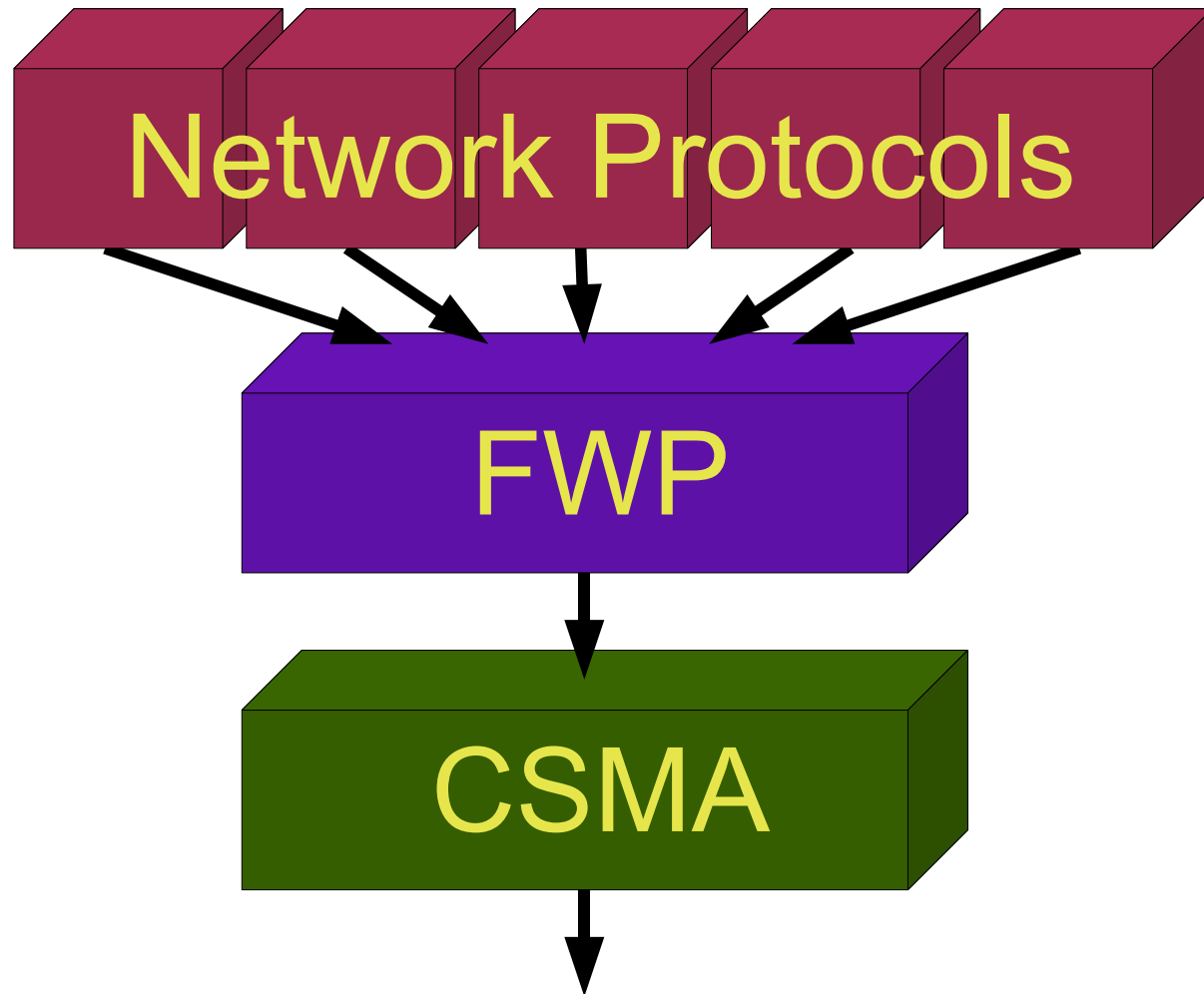
Isolation alone is not enough, the network must also provide fairness.

The Need For Isolation

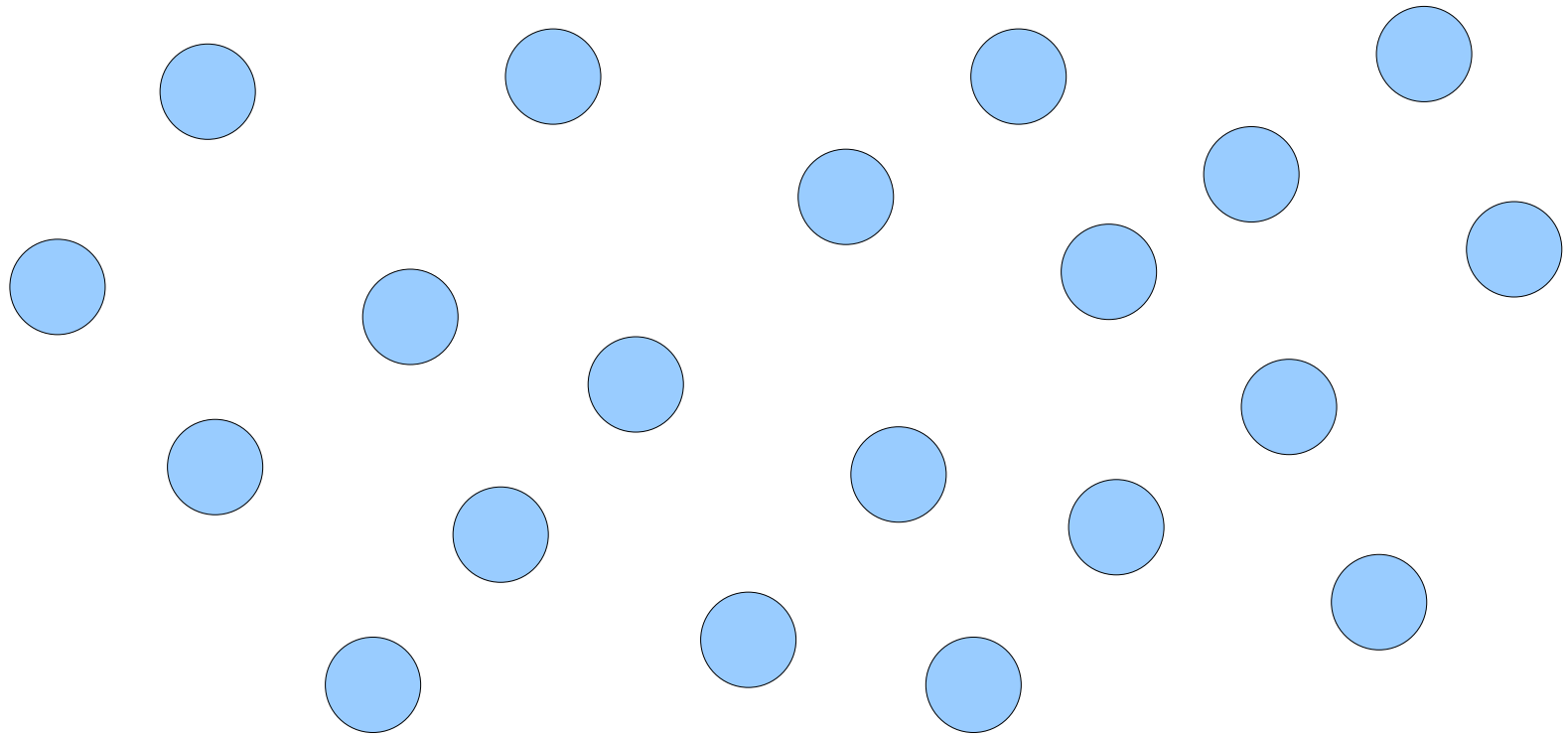
Network Isolation between protocols:

Please be quiet!

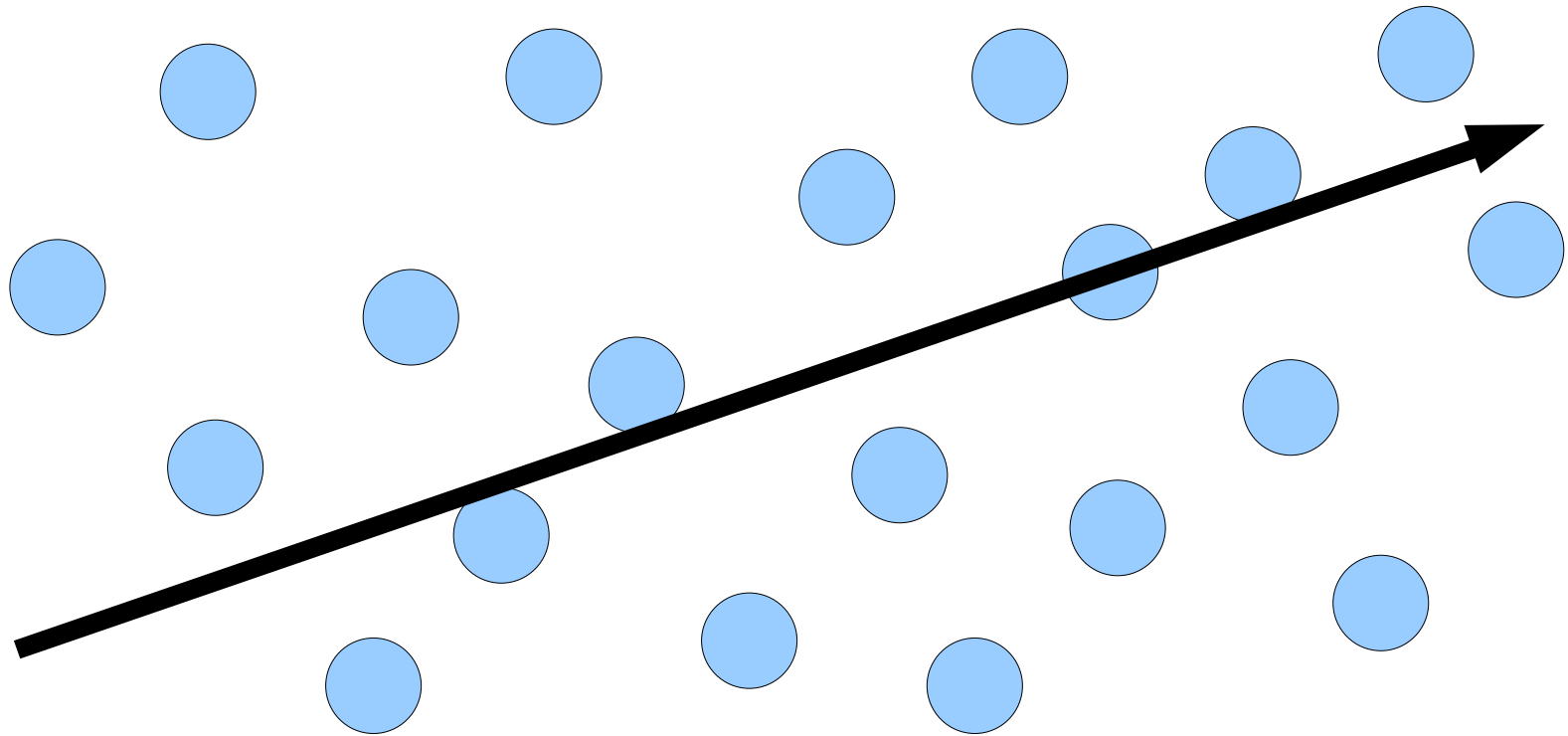
Fair Waiting Protocol



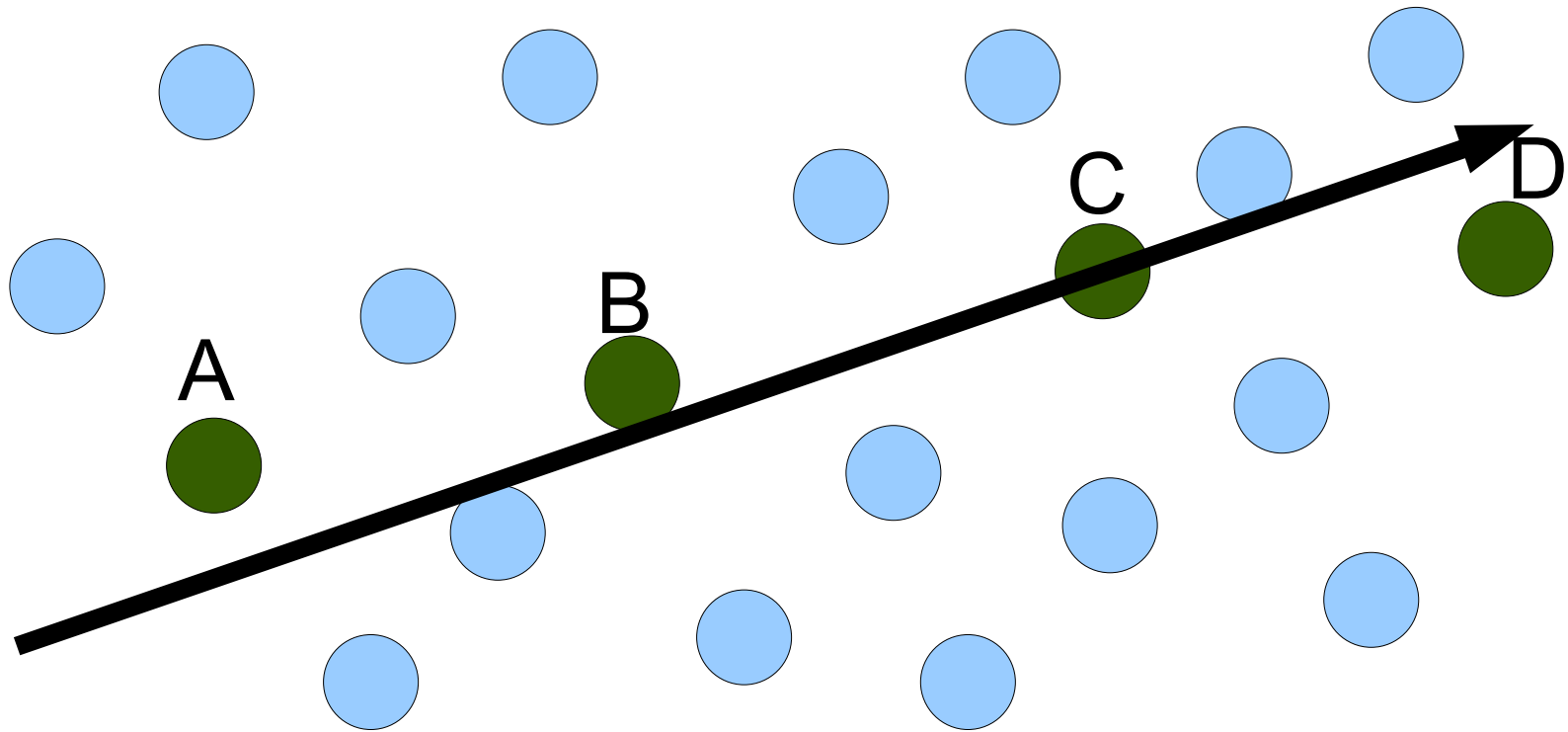
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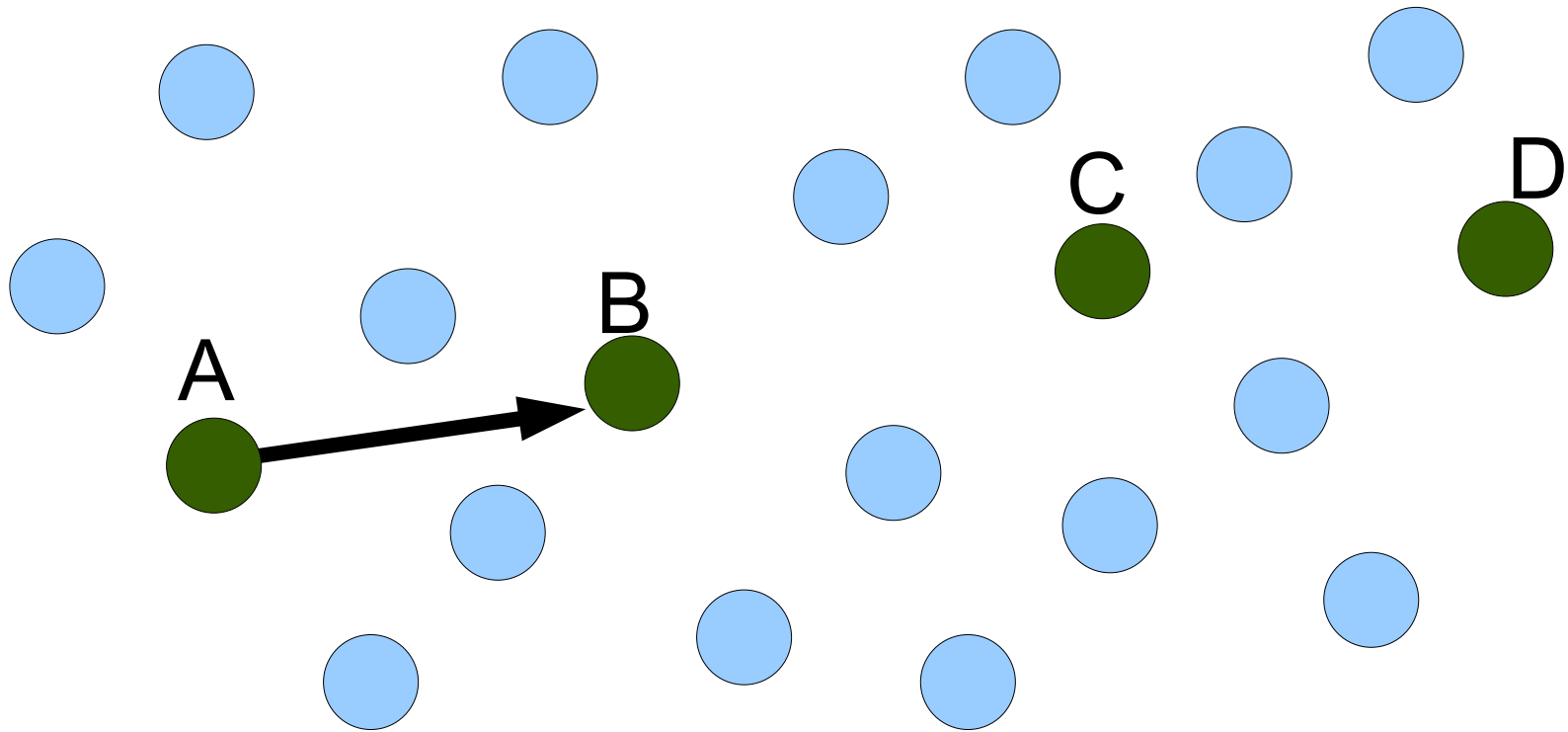
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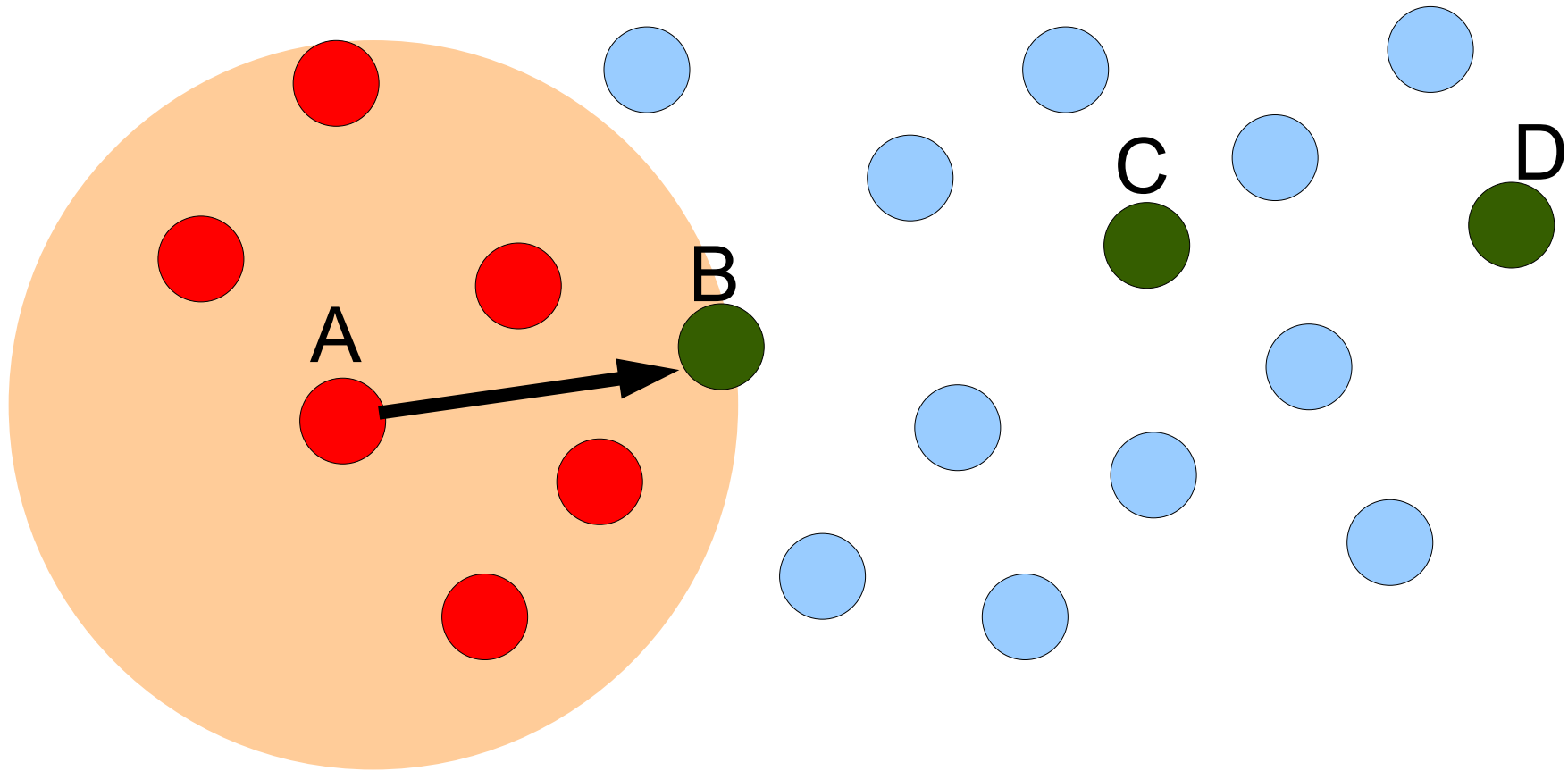
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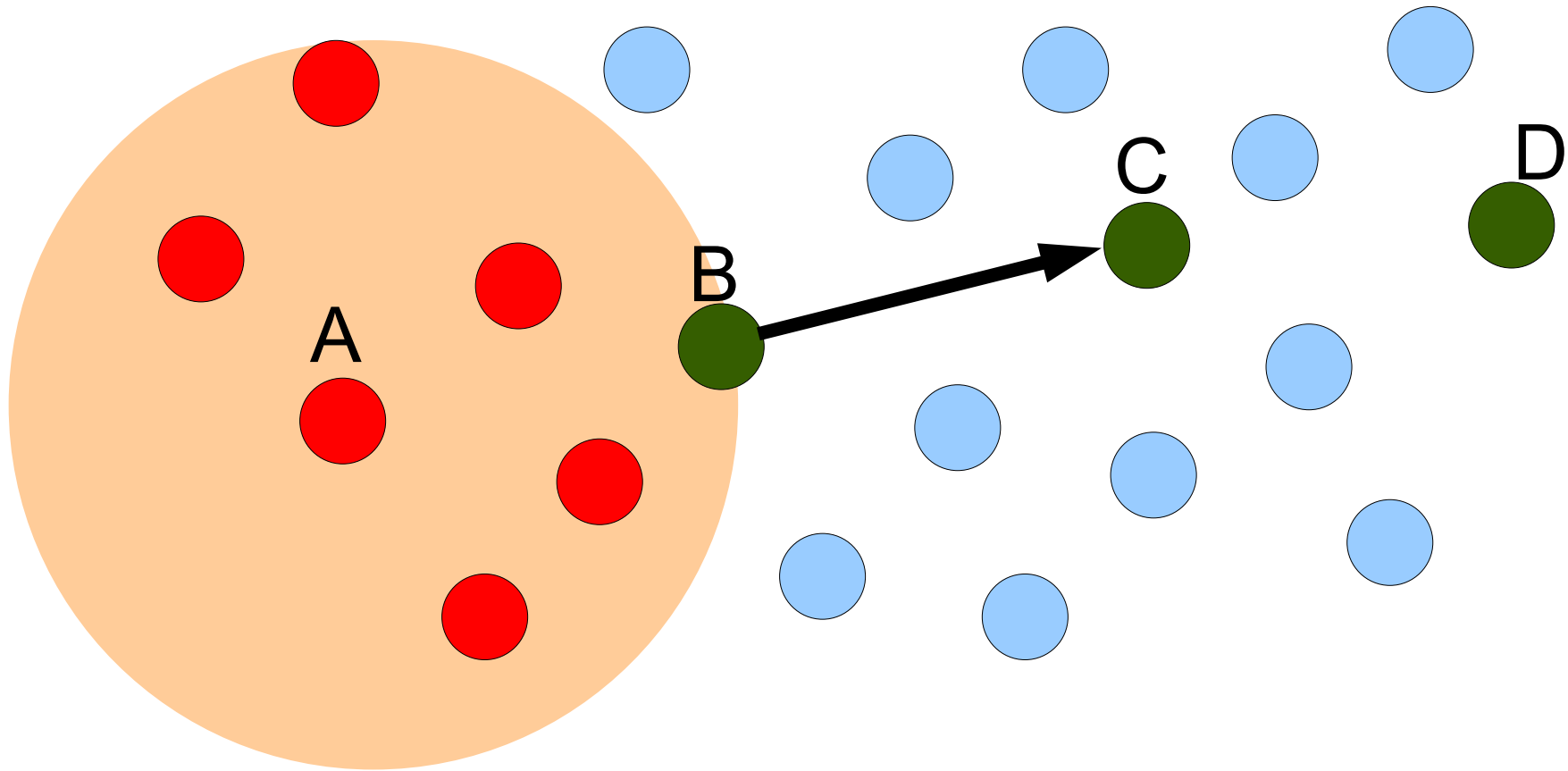
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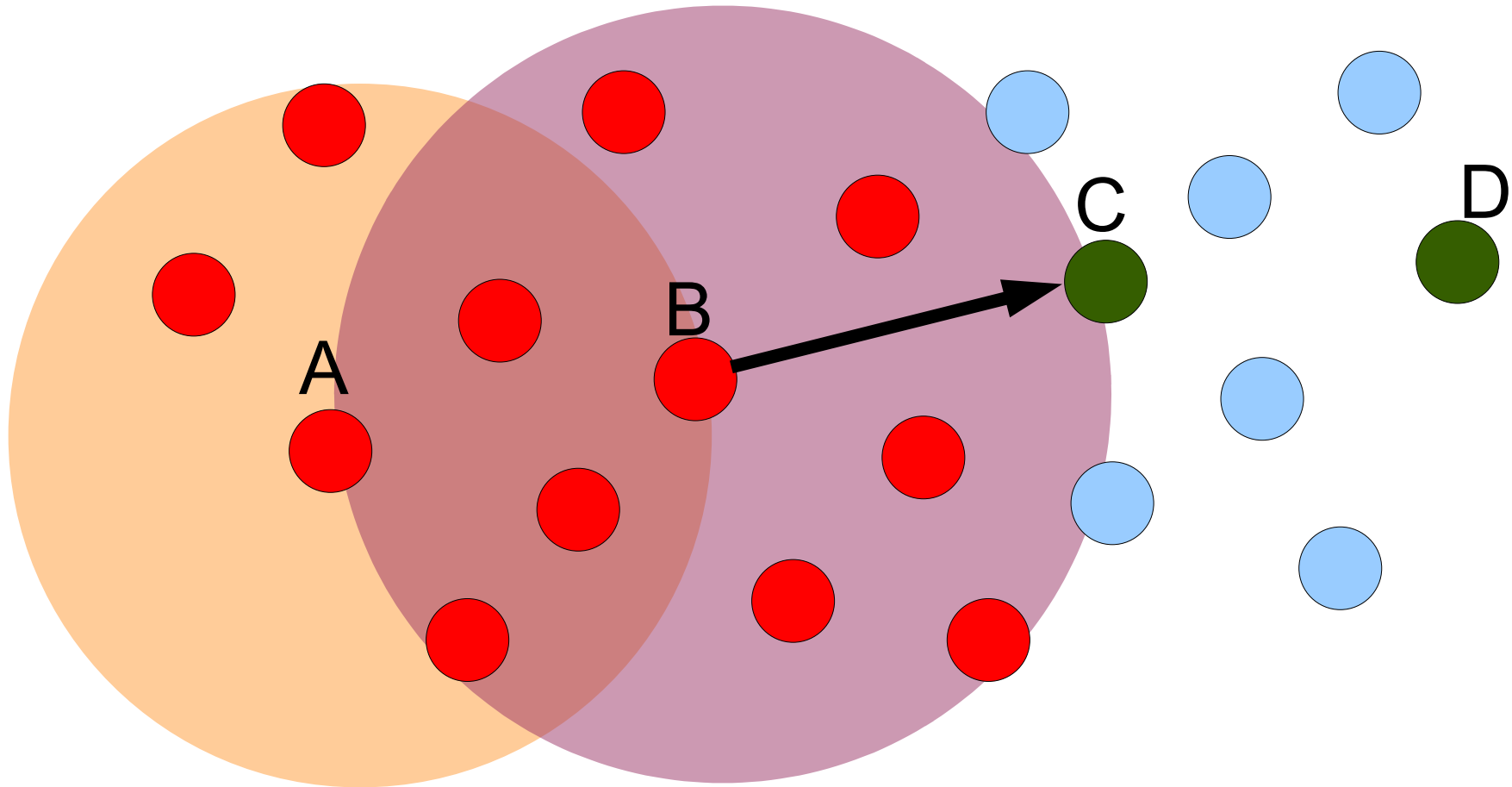
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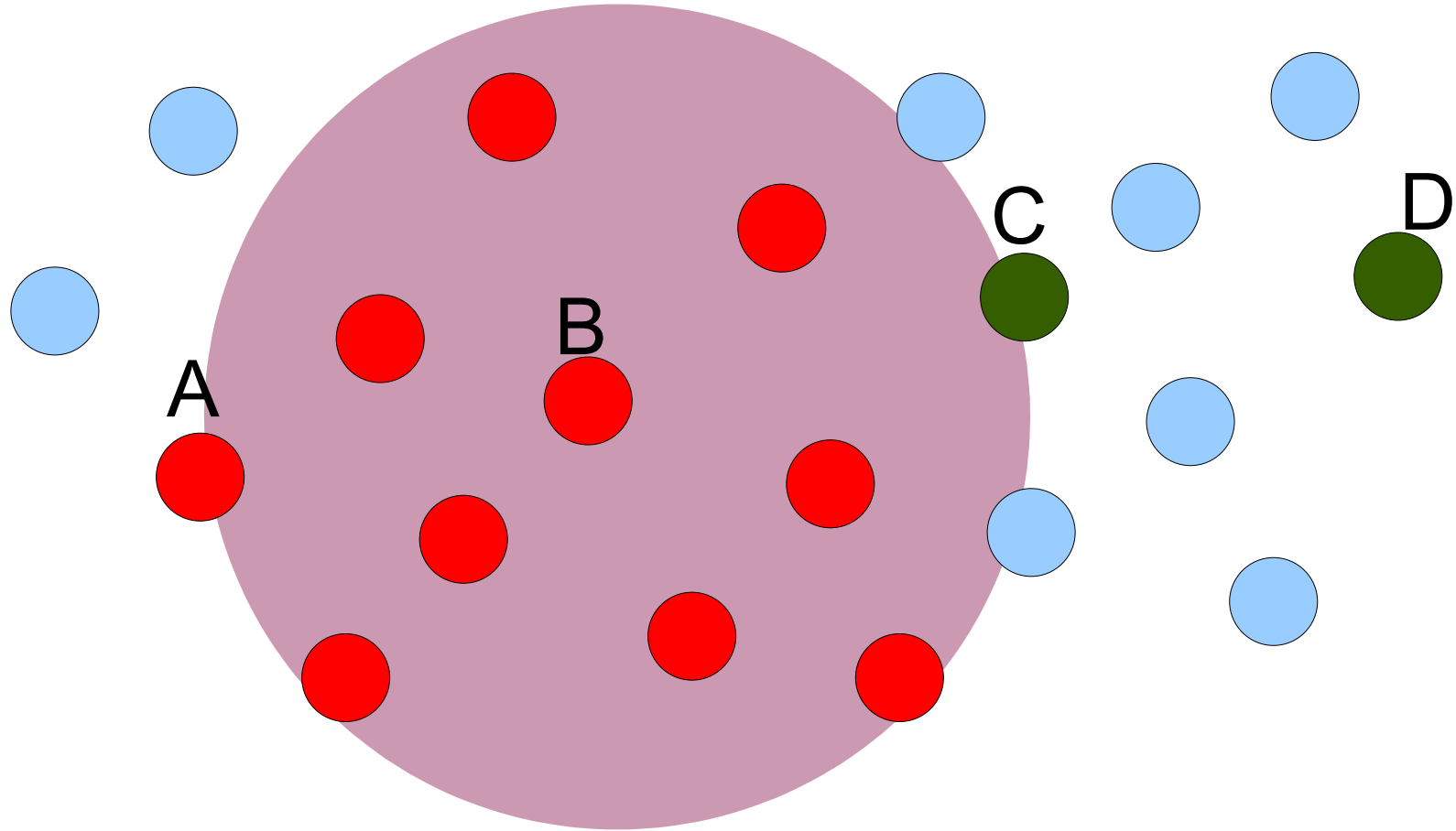
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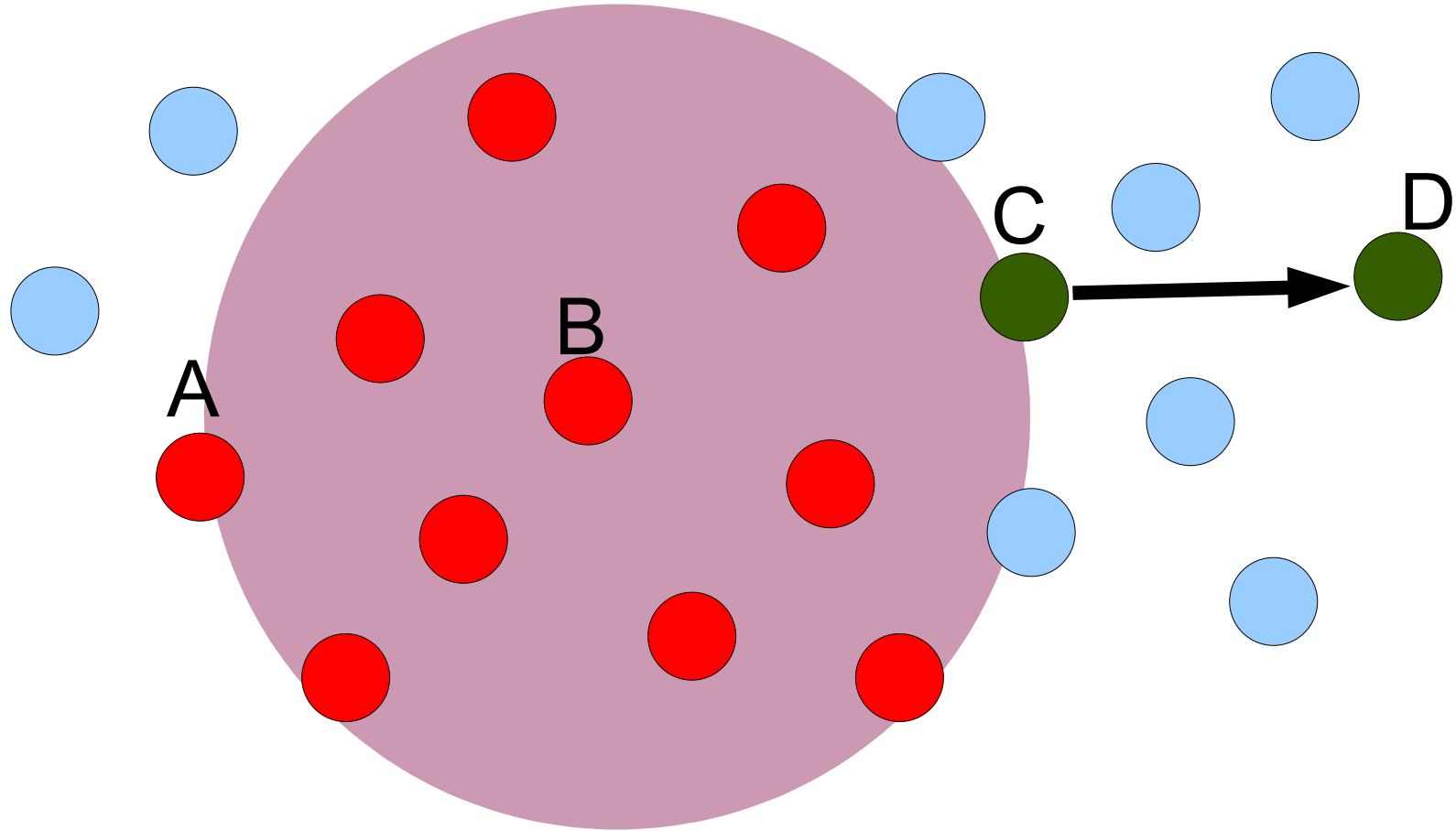
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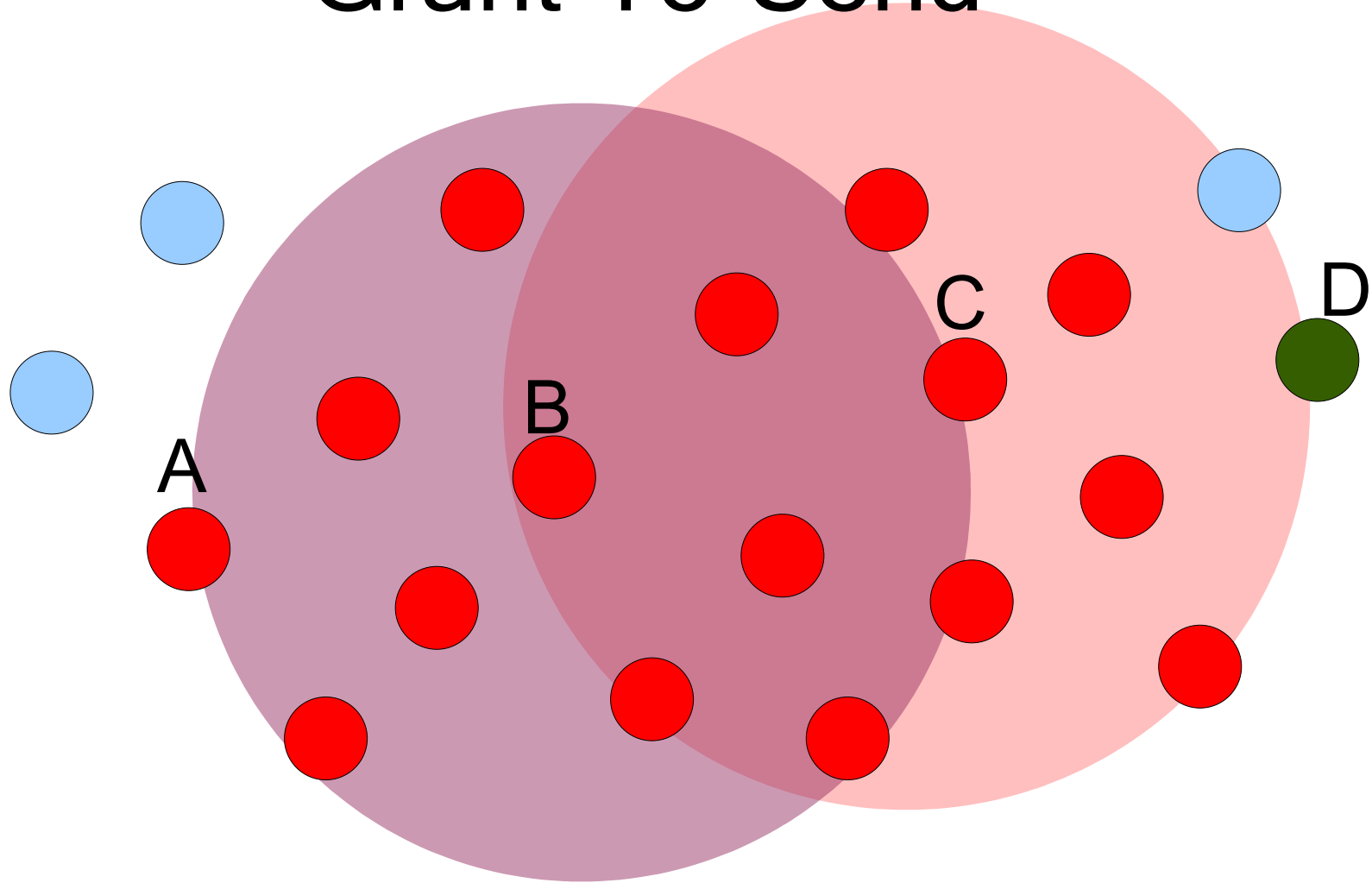
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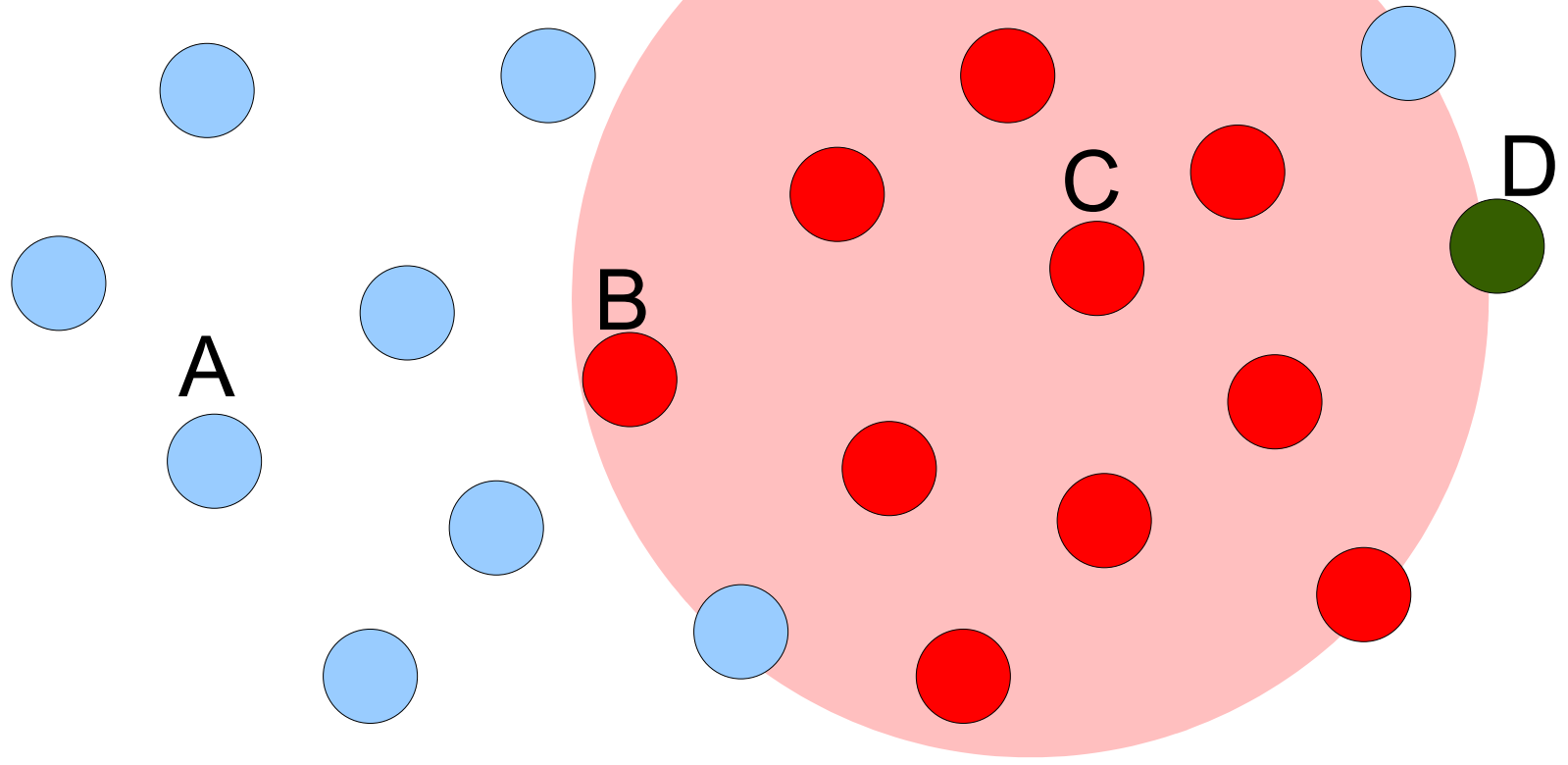
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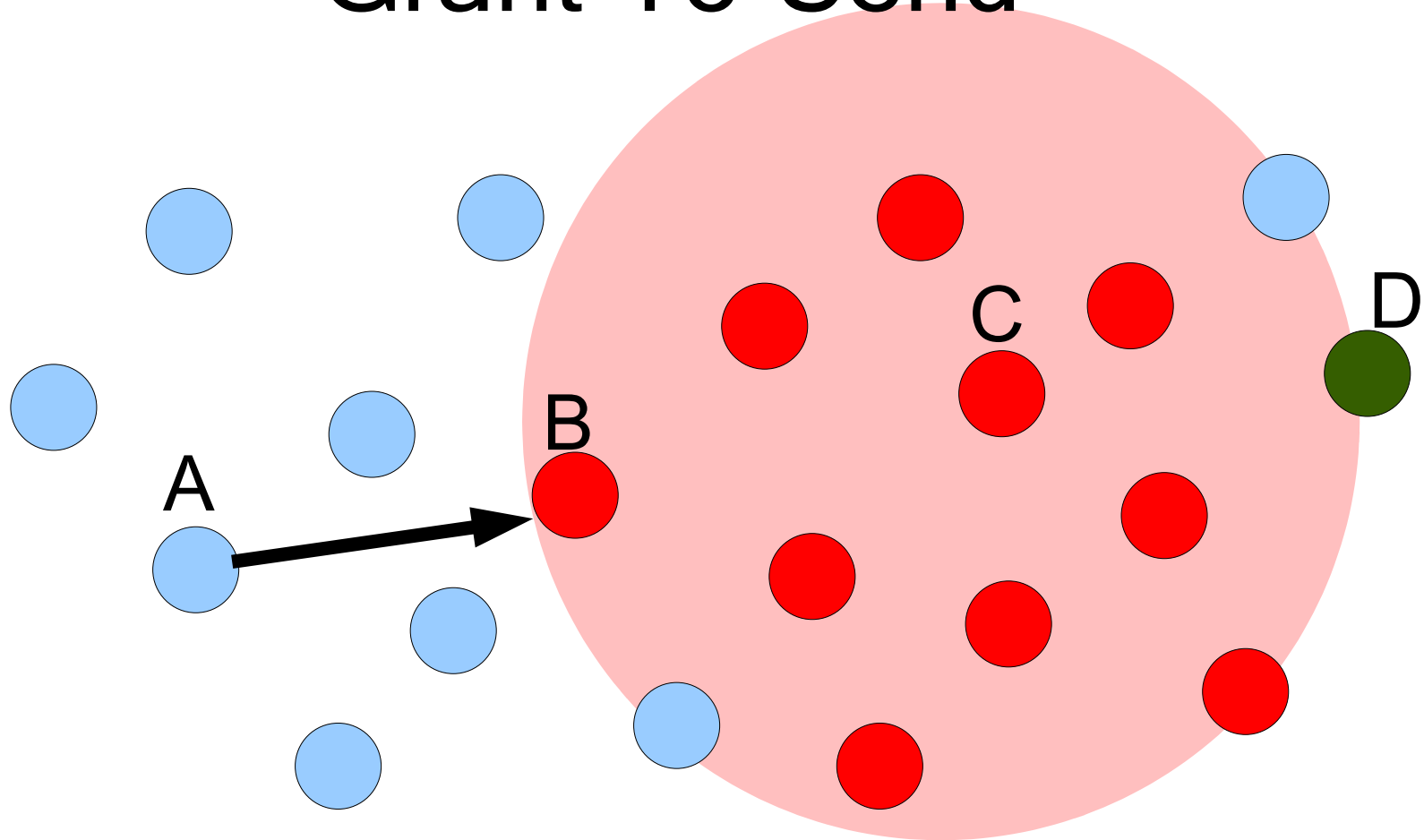
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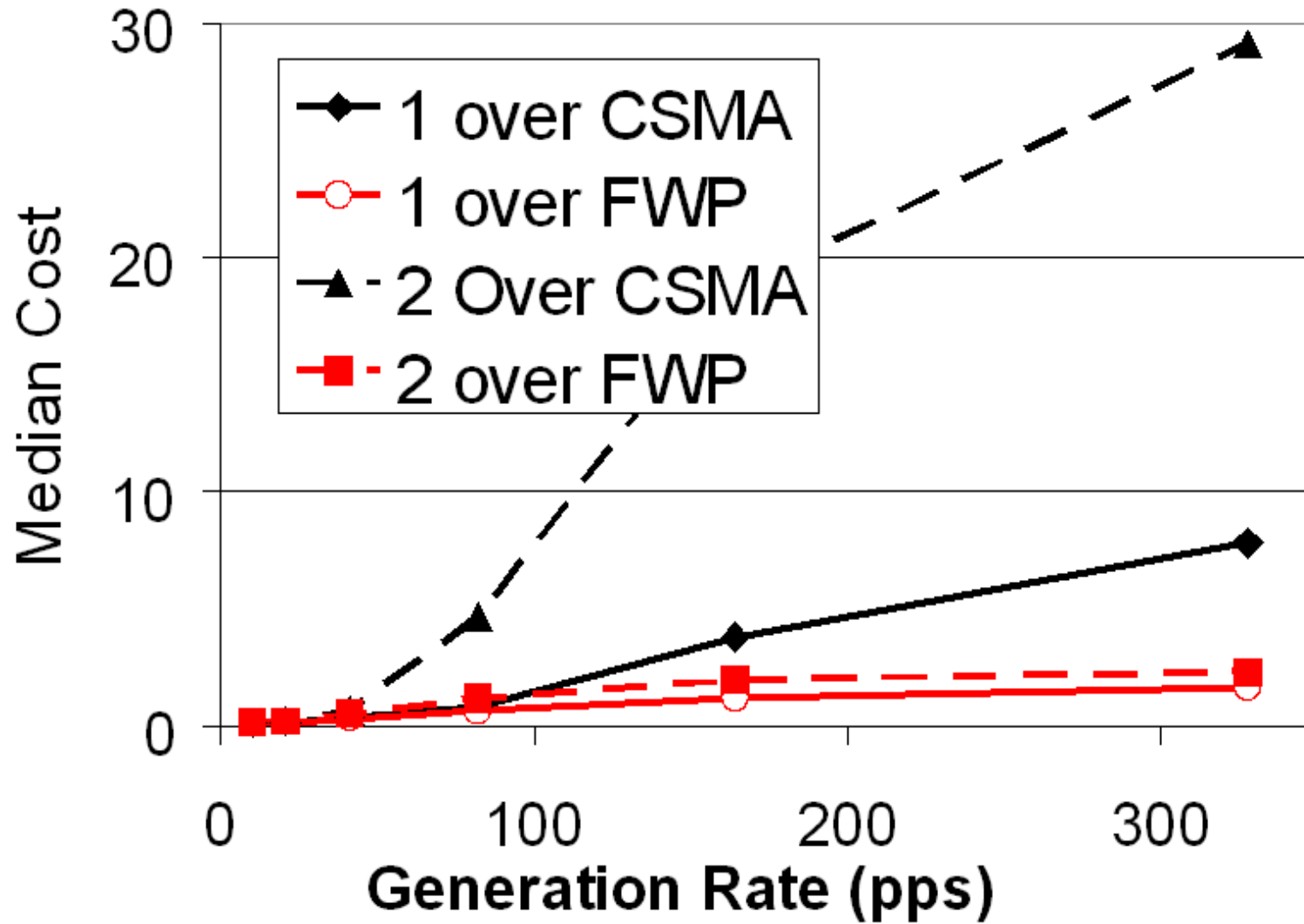
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Grant-To-Send



FWP Isolation



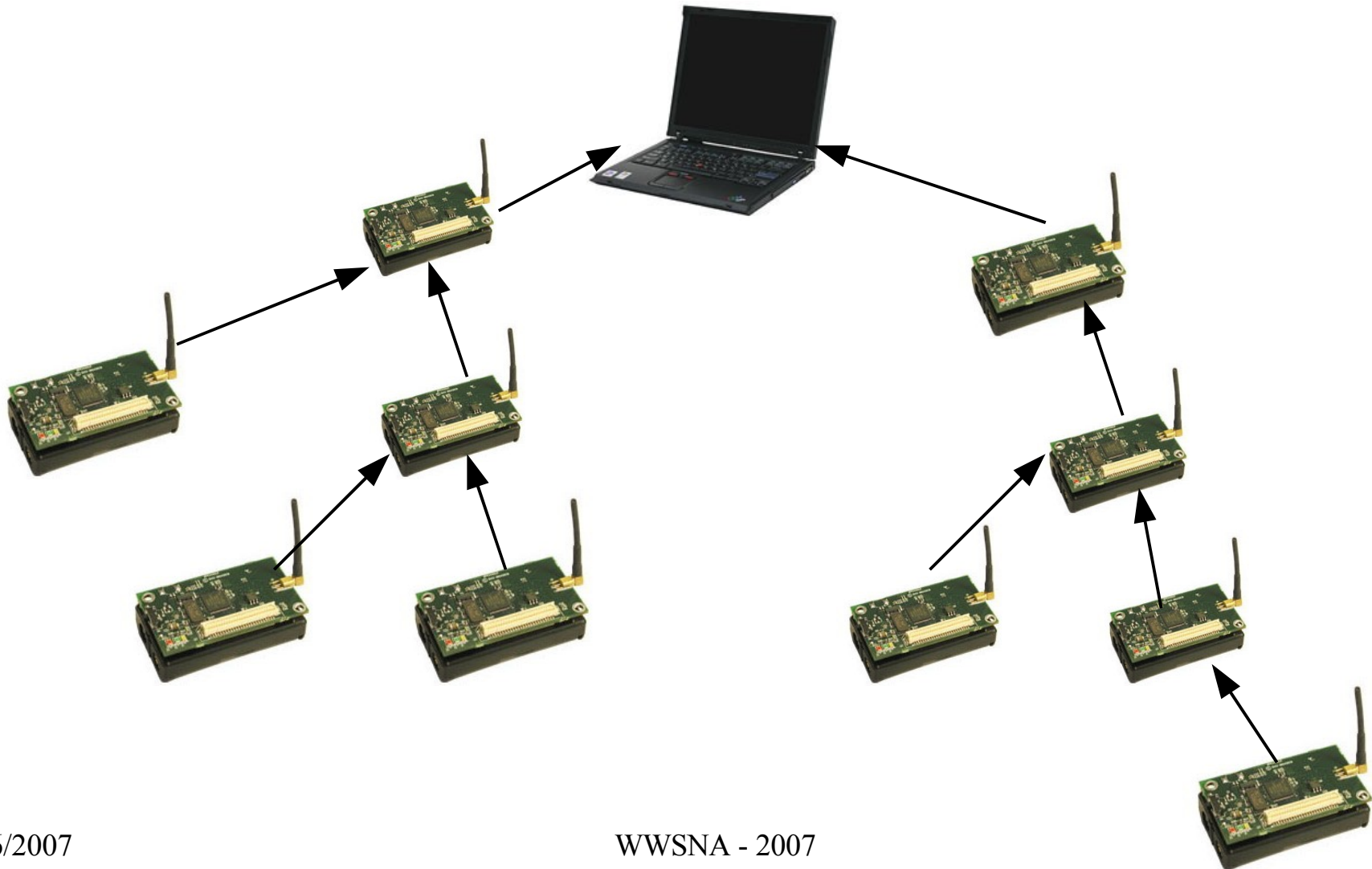
FWP Fairness

Weighted Fair Queuing of protocols based on Grant-to-Send durations and packet lengths.

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A Design Example: Pull Collection Protocol



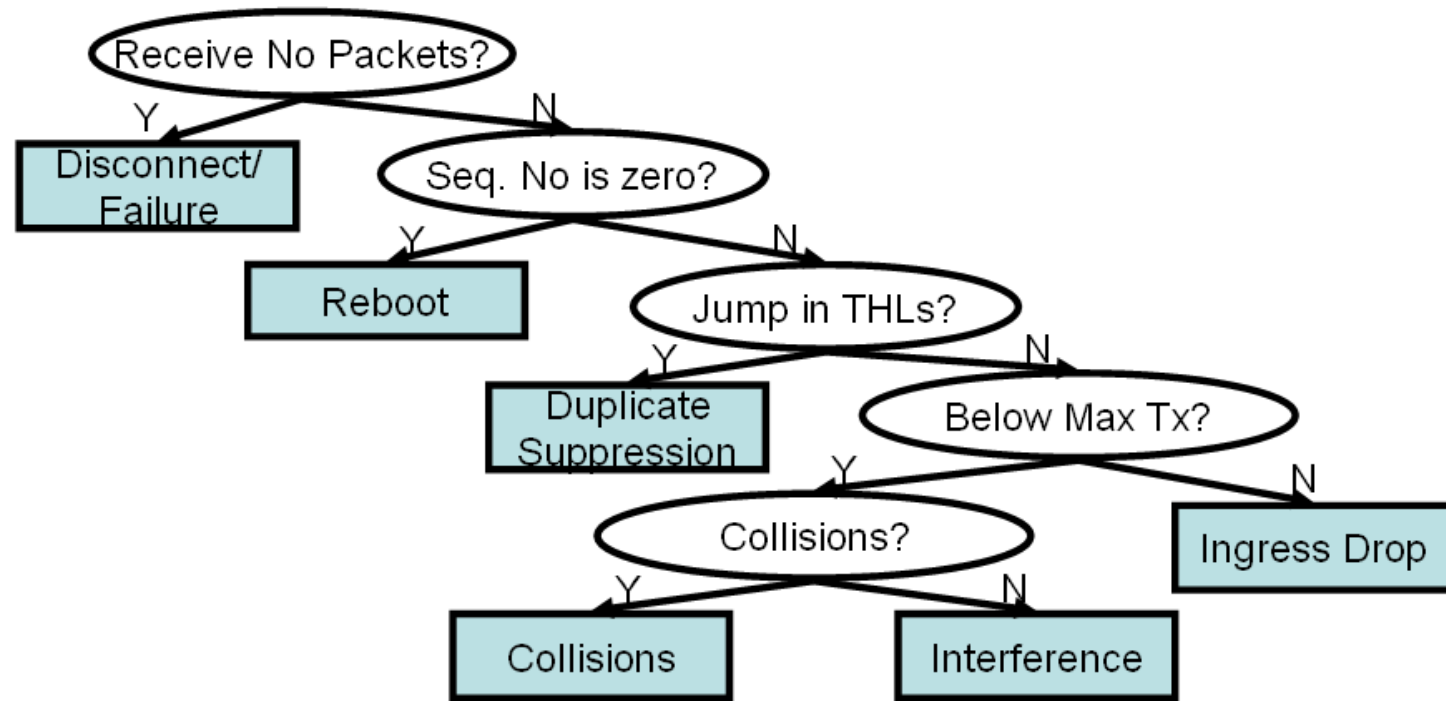
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WWSNA - 2007

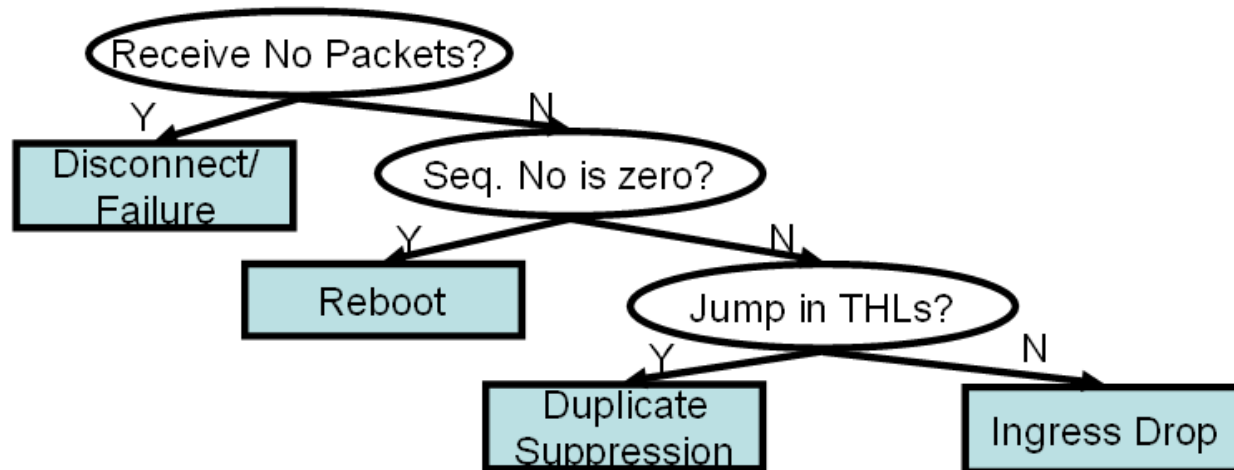
Common Causes of Packet Loss in a Collection Protocol

- Disconnection
- Destruction
- Reboot
- Suppression
- Queue Egress Drop
- Queue Ingress Drop

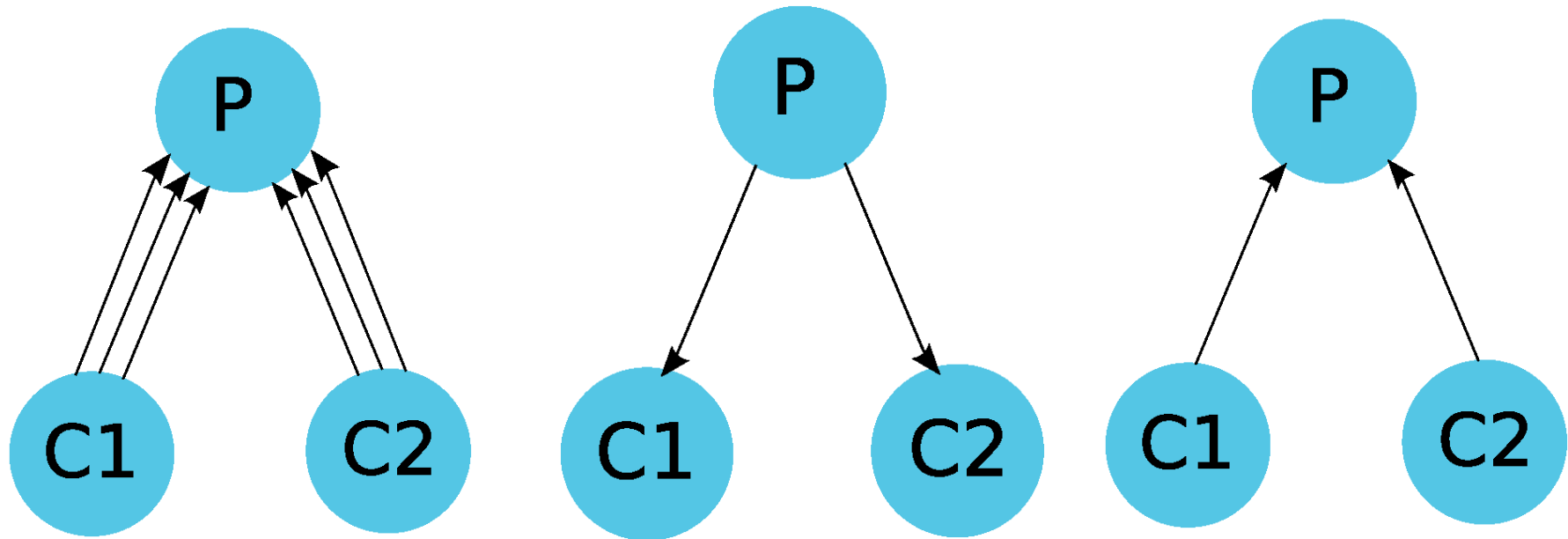
Diagnosing Why Packets Were Lost



Diagnosing Why Packets Were Lost

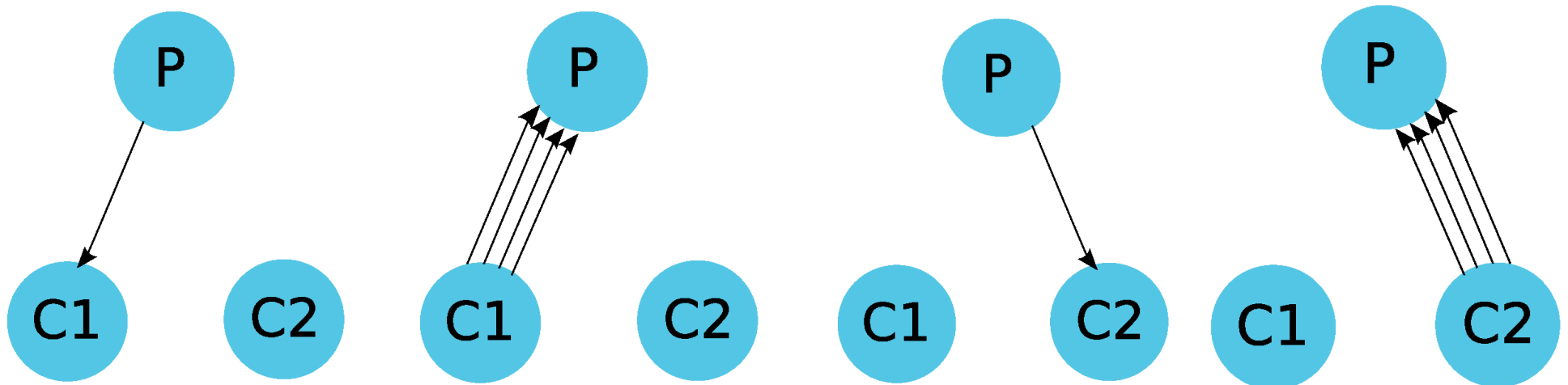


Eliminating Ingress Drops



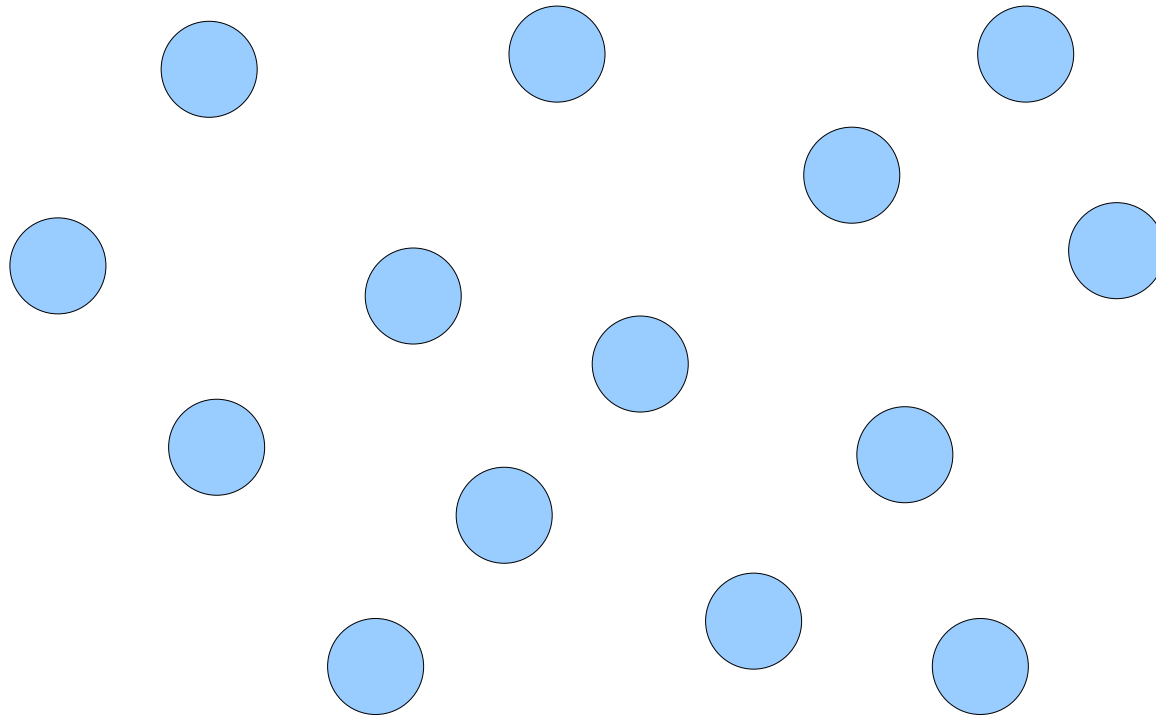
Traditional Rate Control

Eliminating Ingress Drops

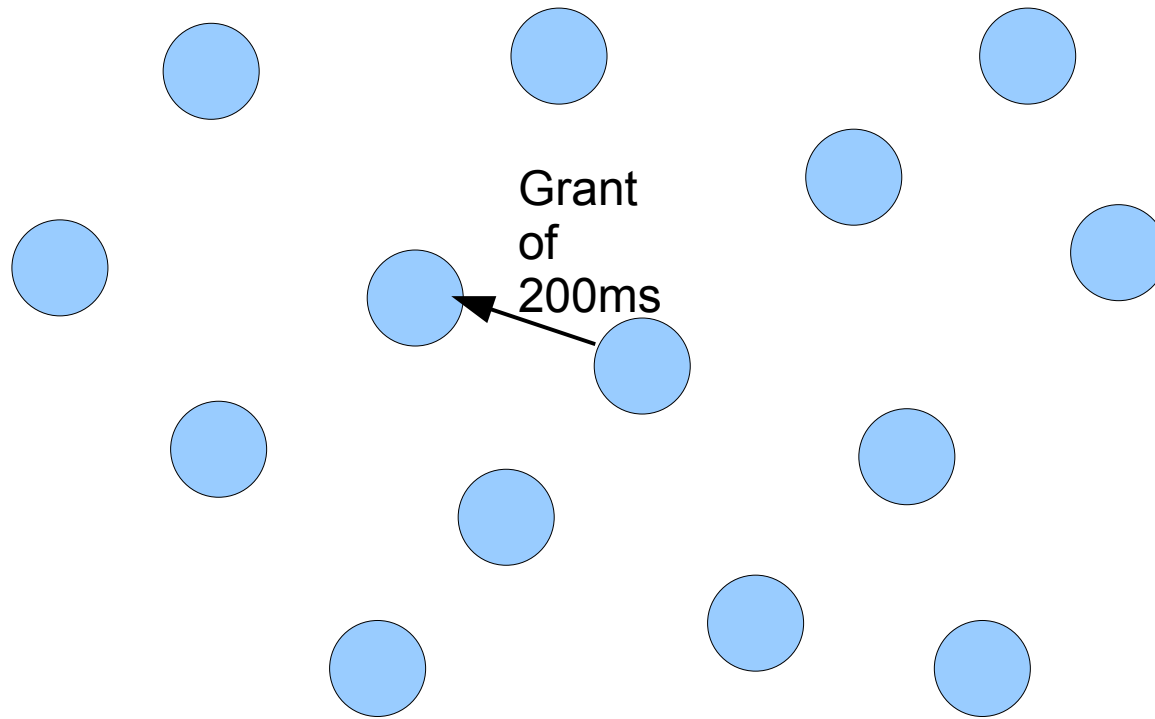


Pull-Based Rate Control

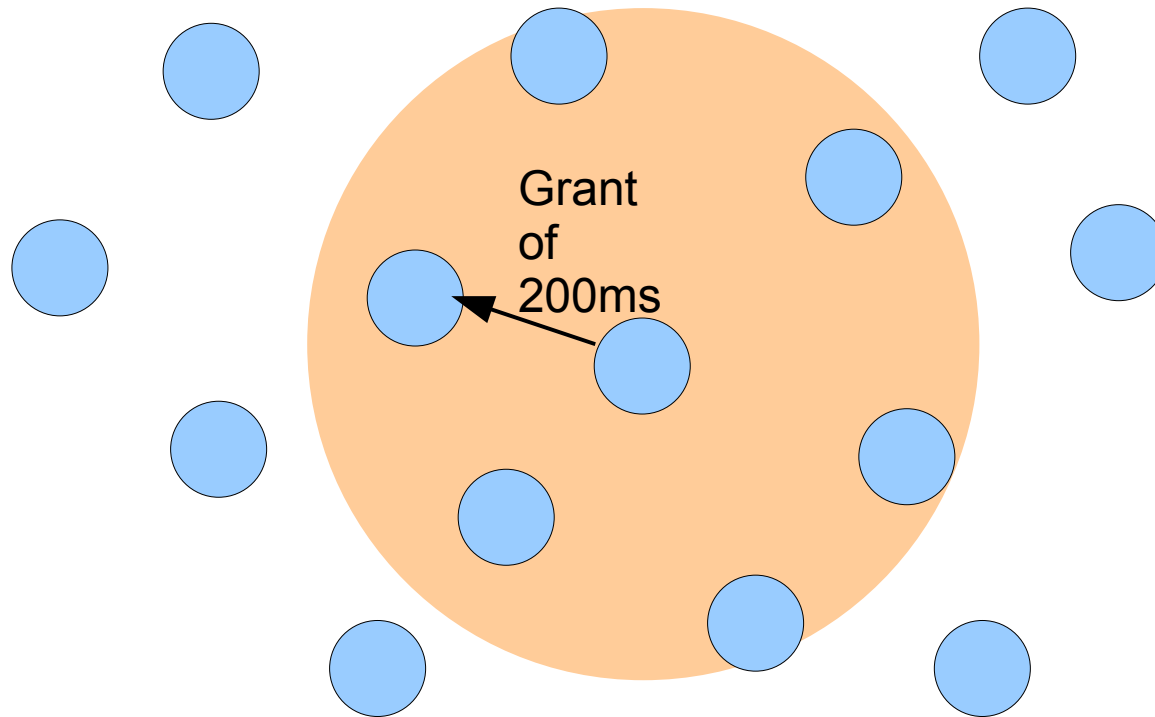
Using FWP For Bursts



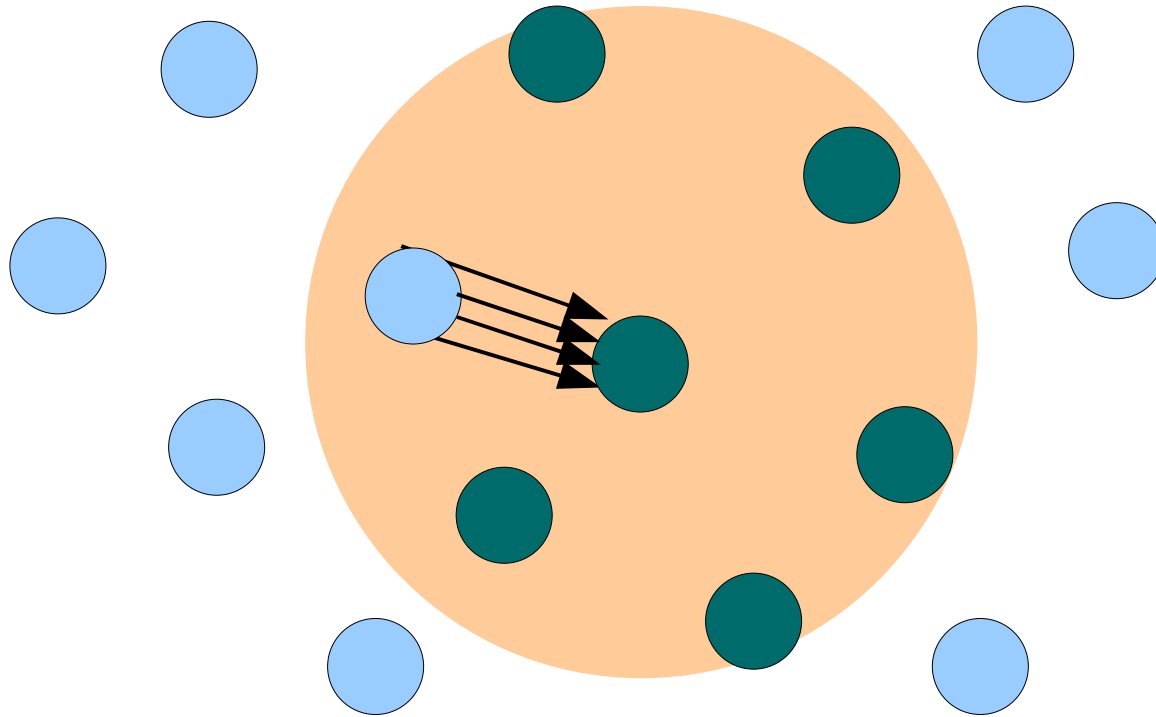
Using FWP For Bursts



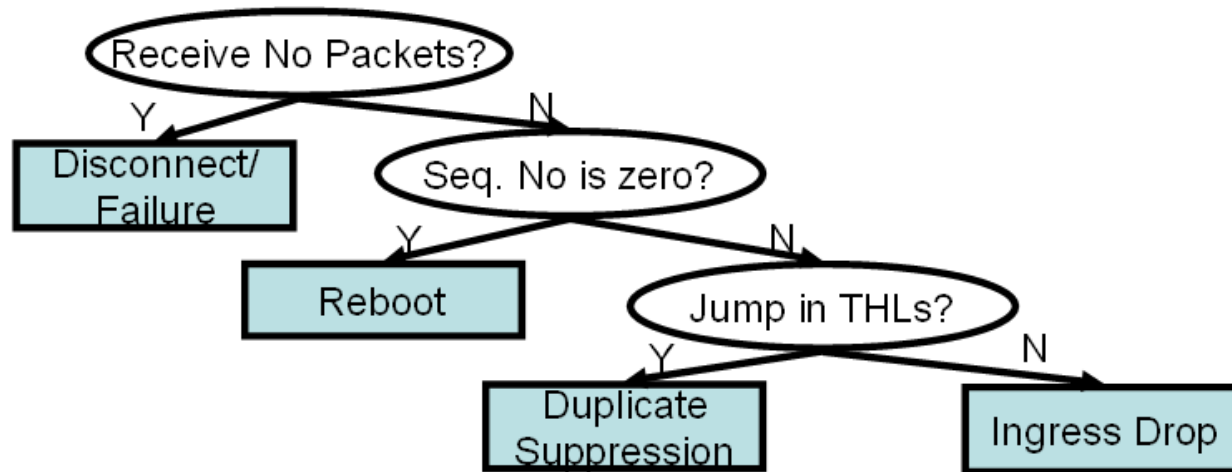
Using FWP For Bursts



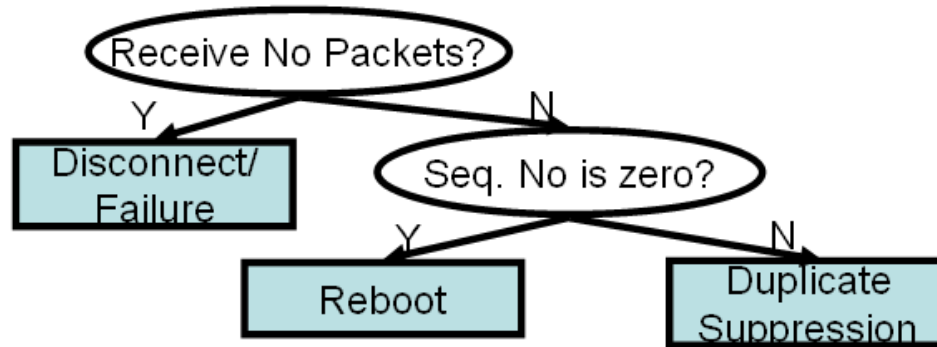
Using FWP For Bursts



Eliminating Ingress Drops



Eliminating Ingress Drops



Traverse the remainder with information included in packets, used by the protocol itself

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Extensions & Limitations- The Cost of Visibility

- Isolation and fairness introduce delay, increasing latencies
- Under light loads, we can use zero grant-to-send times.

Extensions & Limitations- Low Power

- Low-Power listening in conjunction with packet bursts.

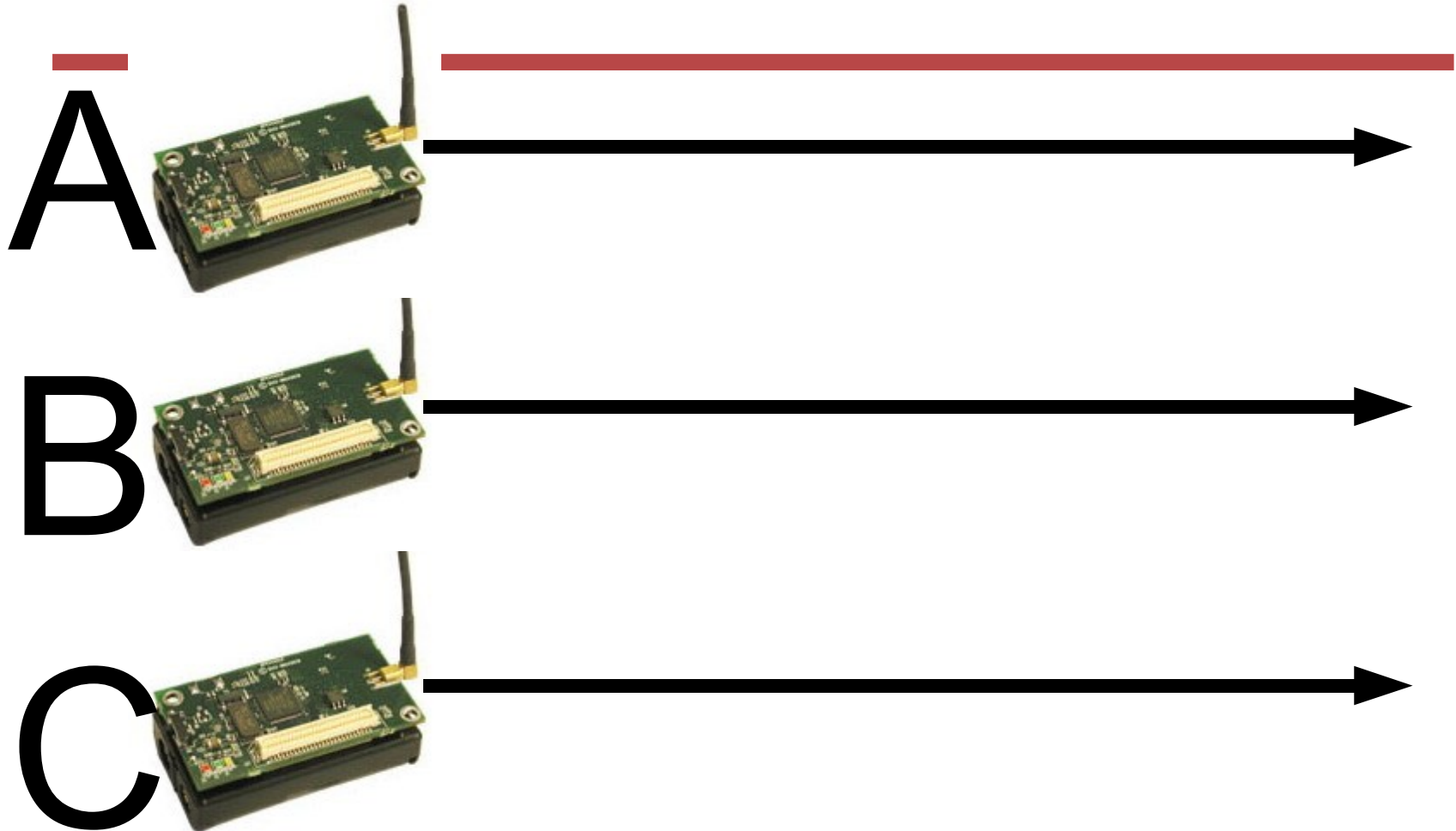
Extensions & Limitations- Isolation & Fairness

- An individual mote must provide system isolation and fairness.
- Higher-layer network protocols can provide fairness across network flows

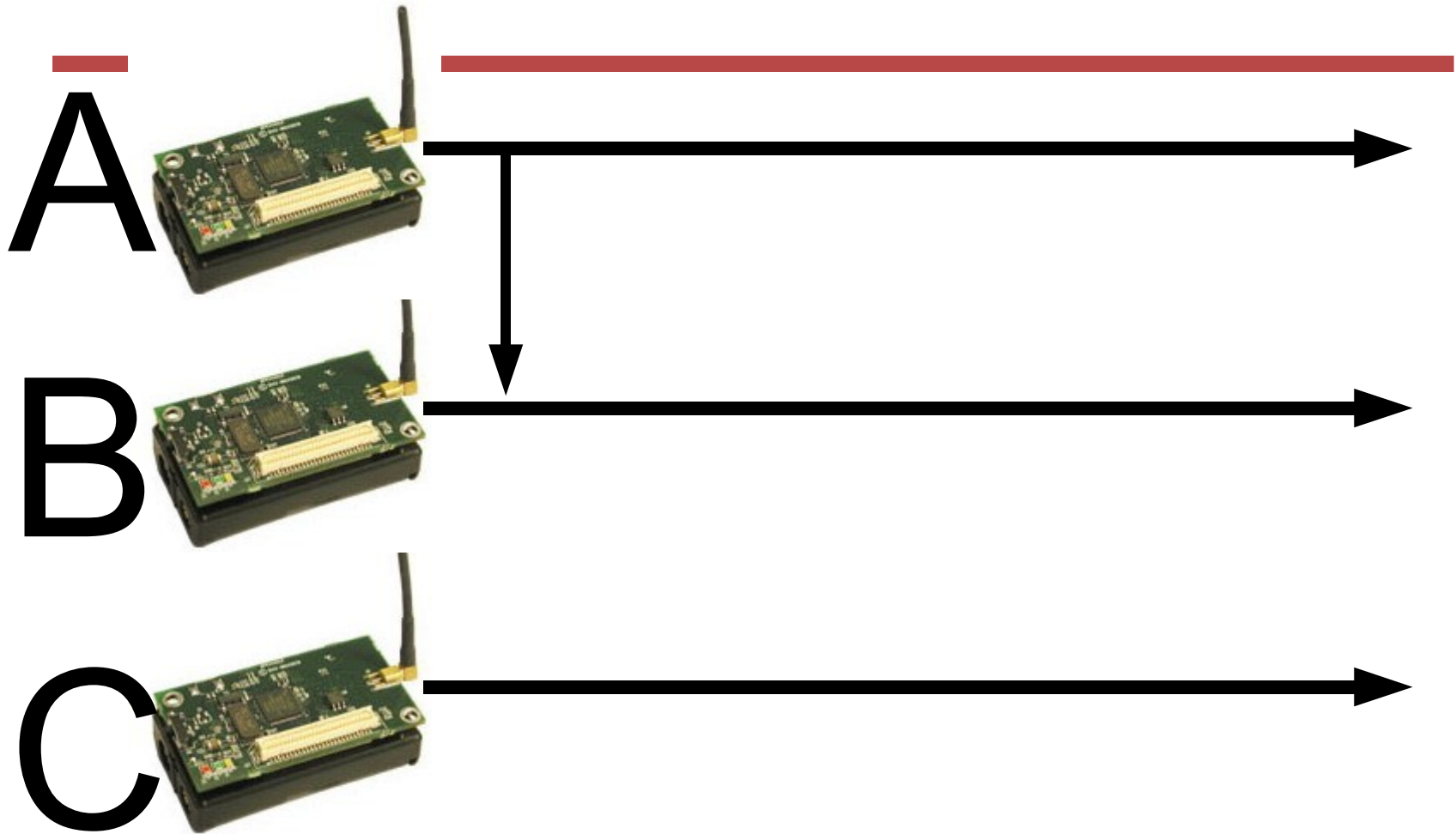
Comments & Questions?

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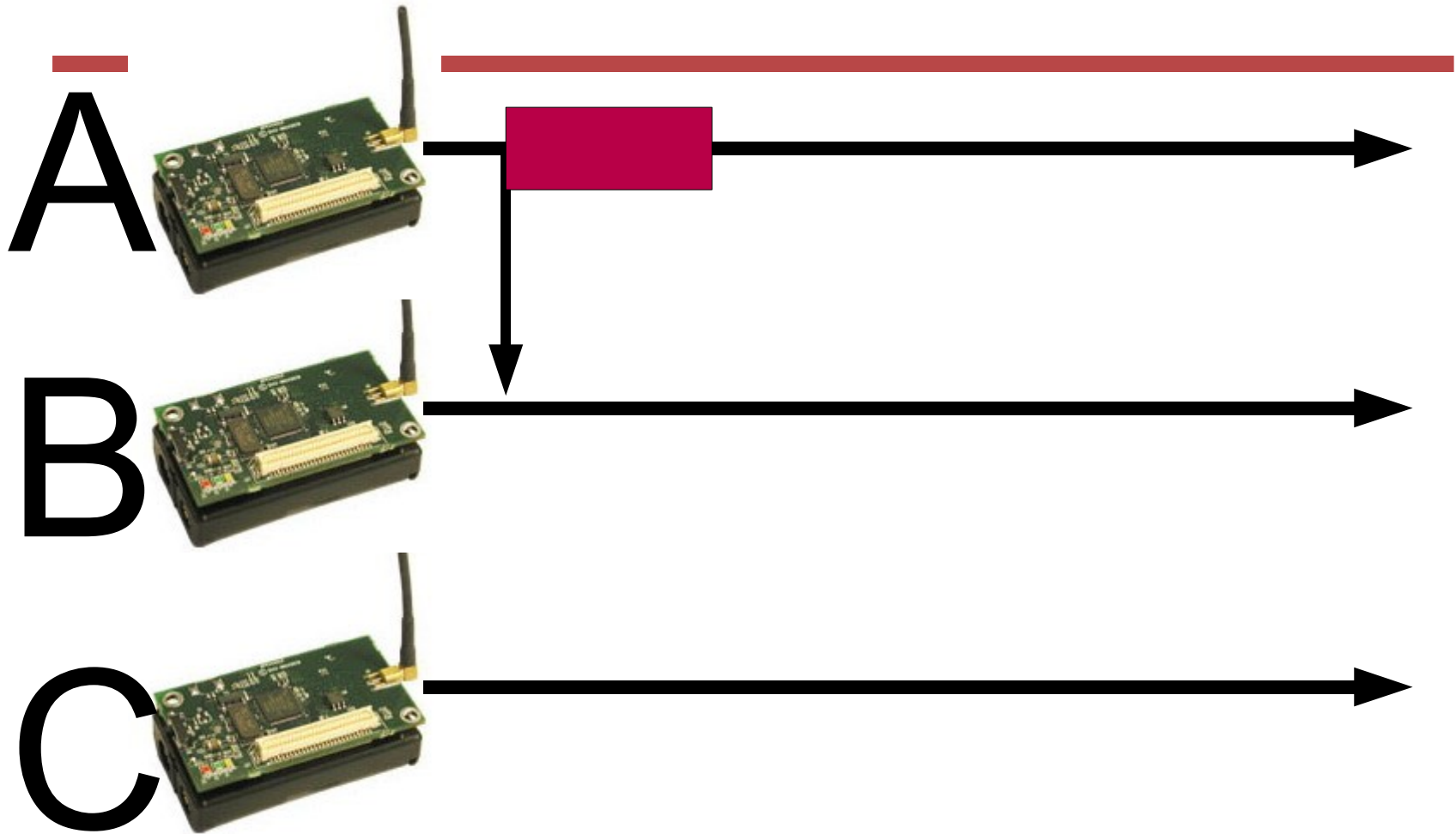
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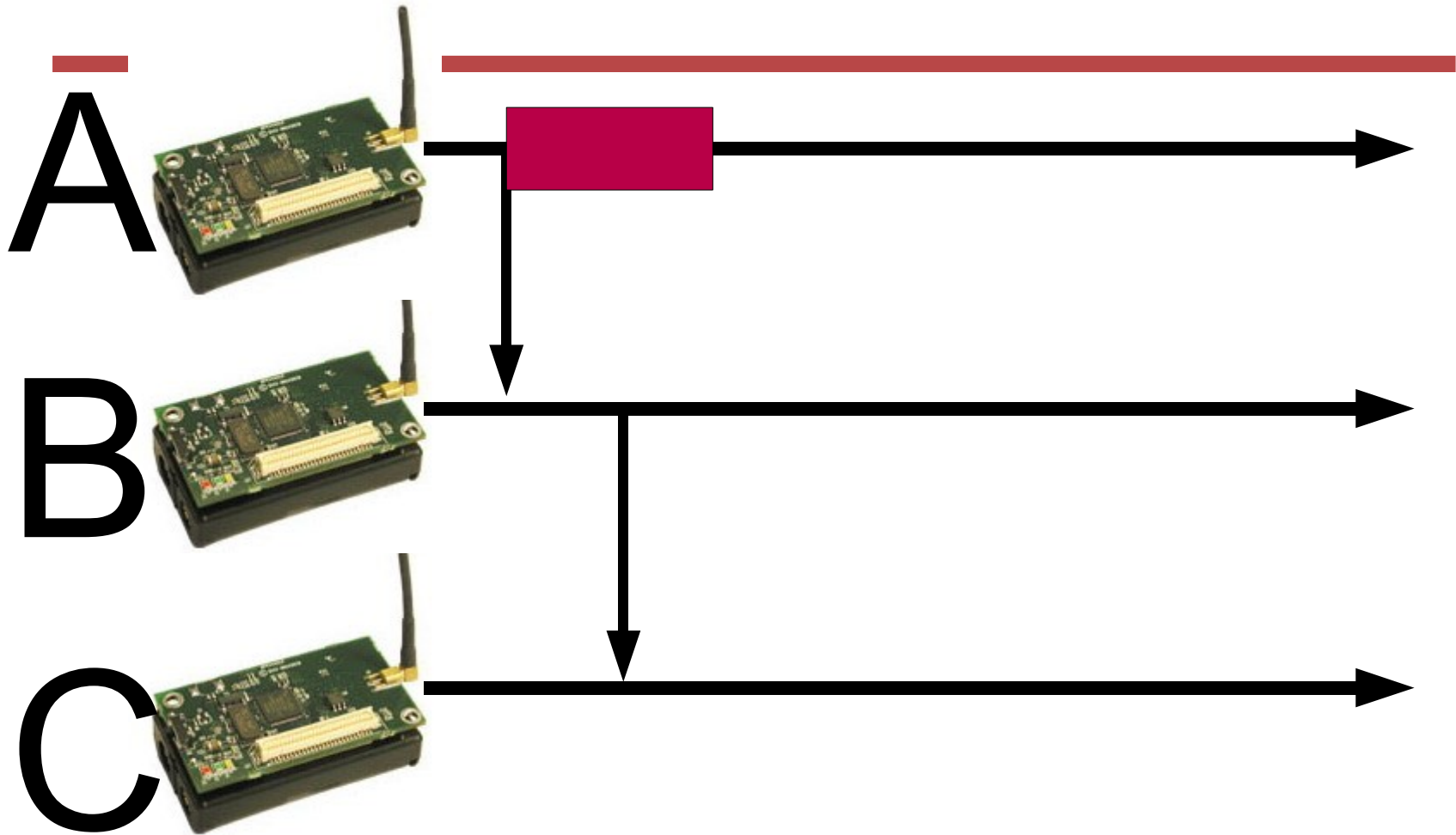
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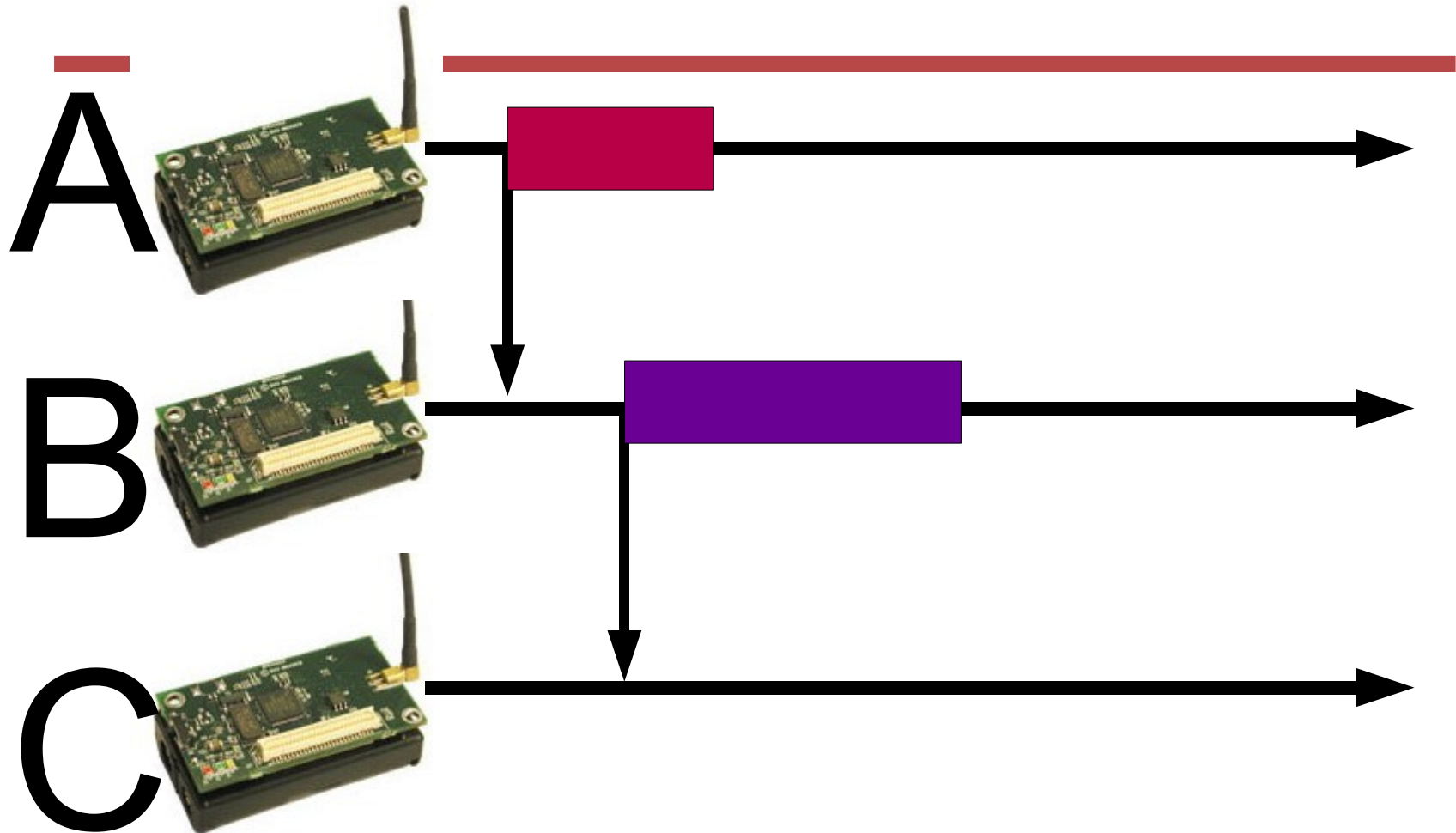
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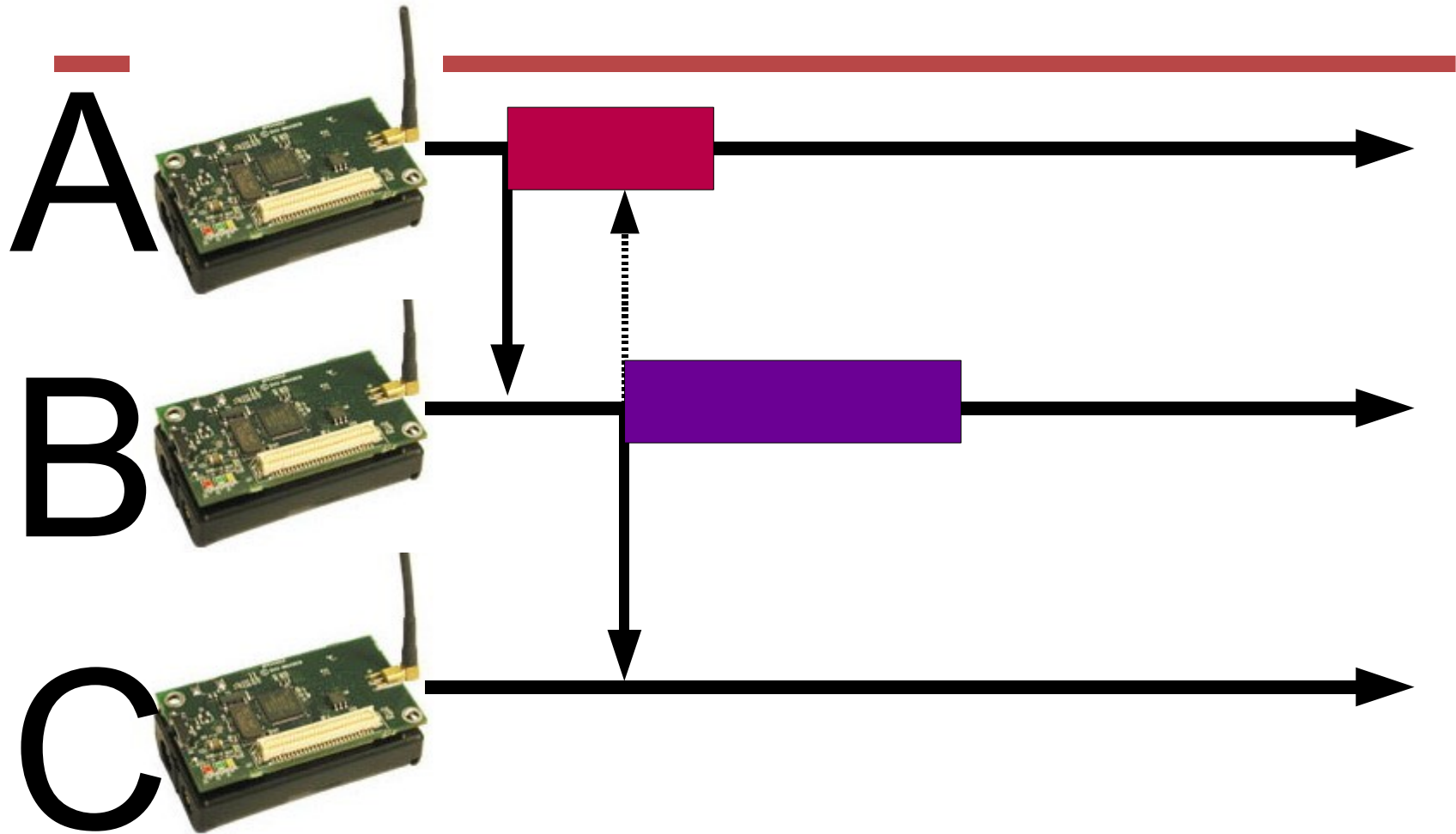
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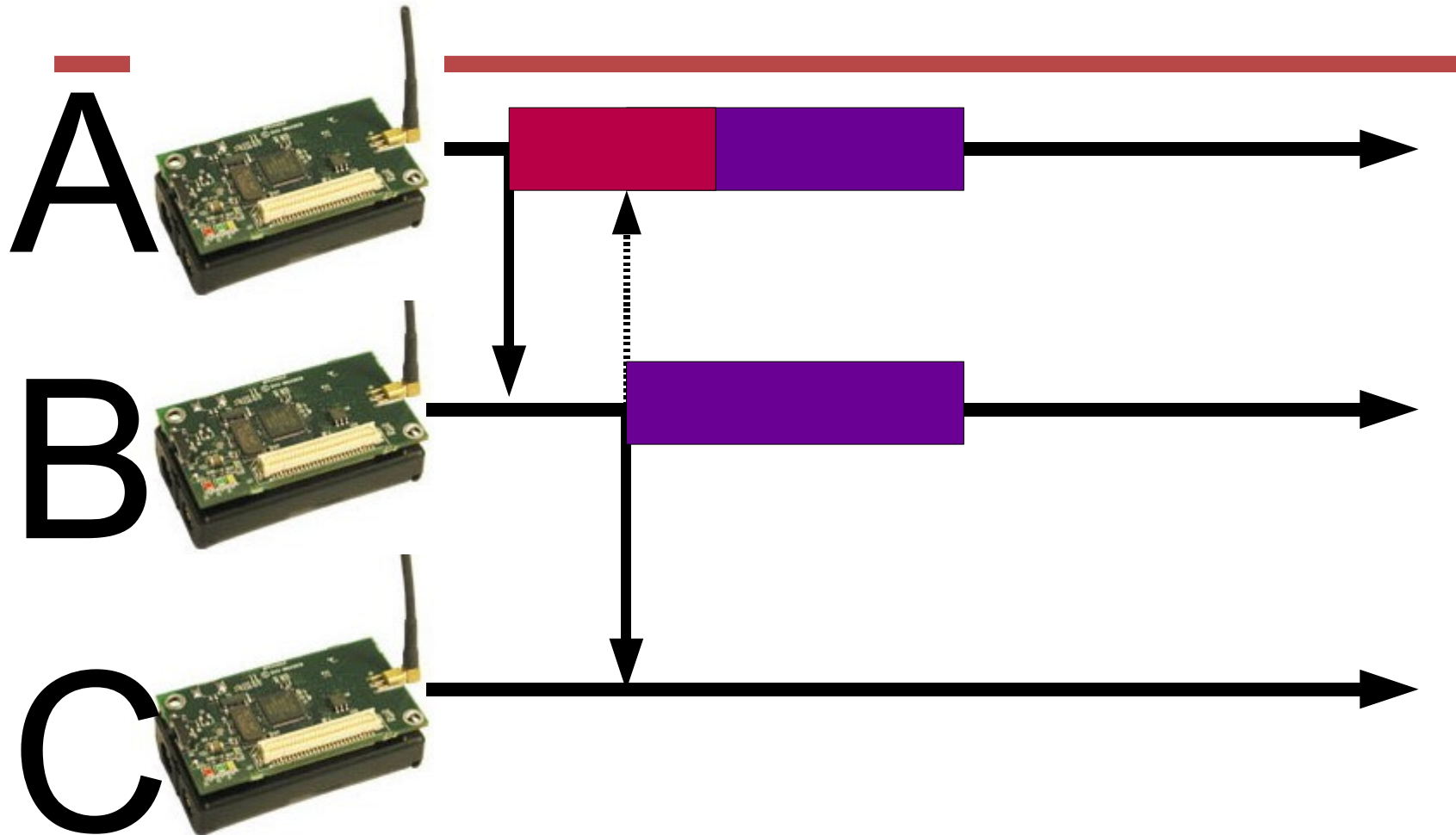
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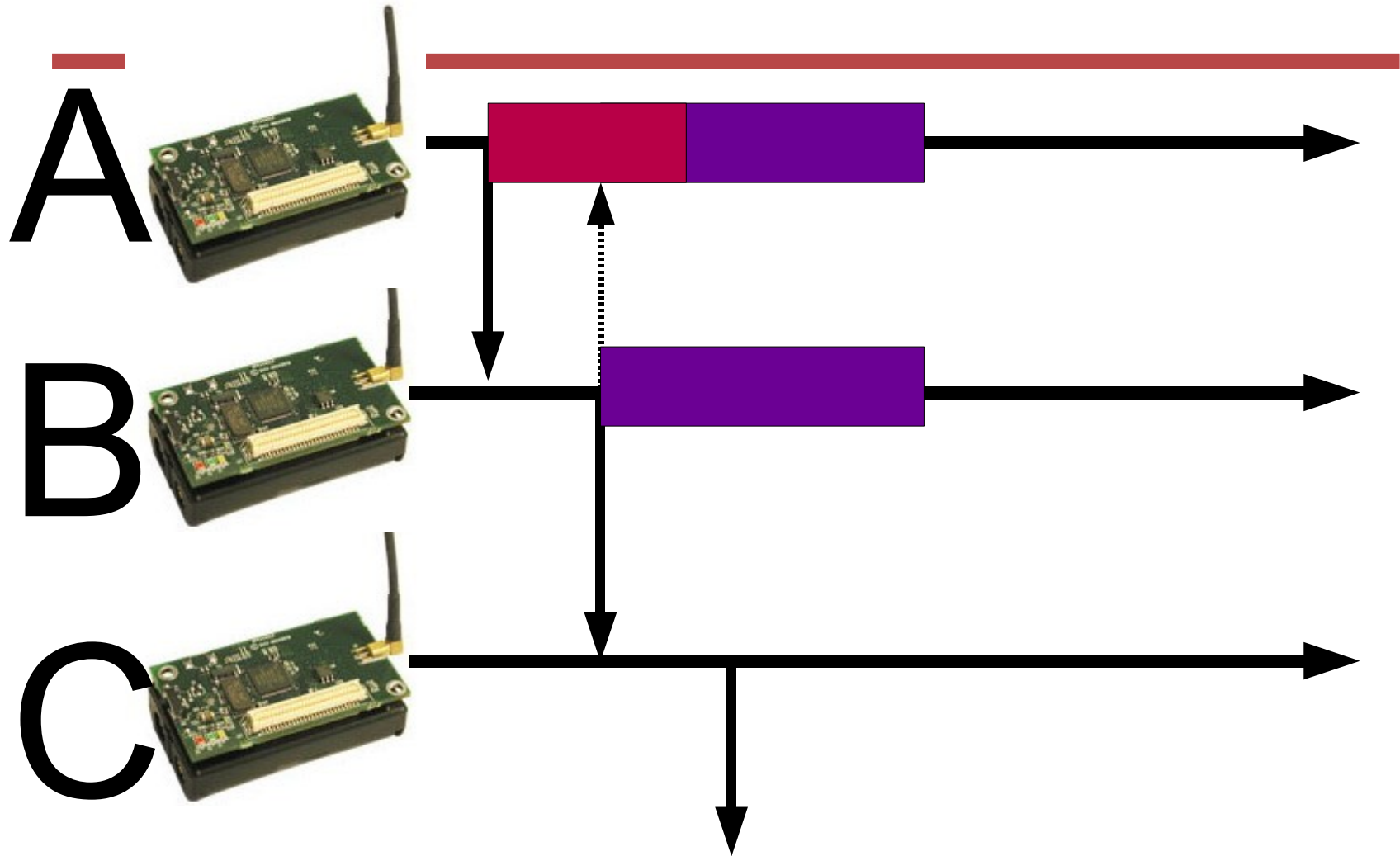
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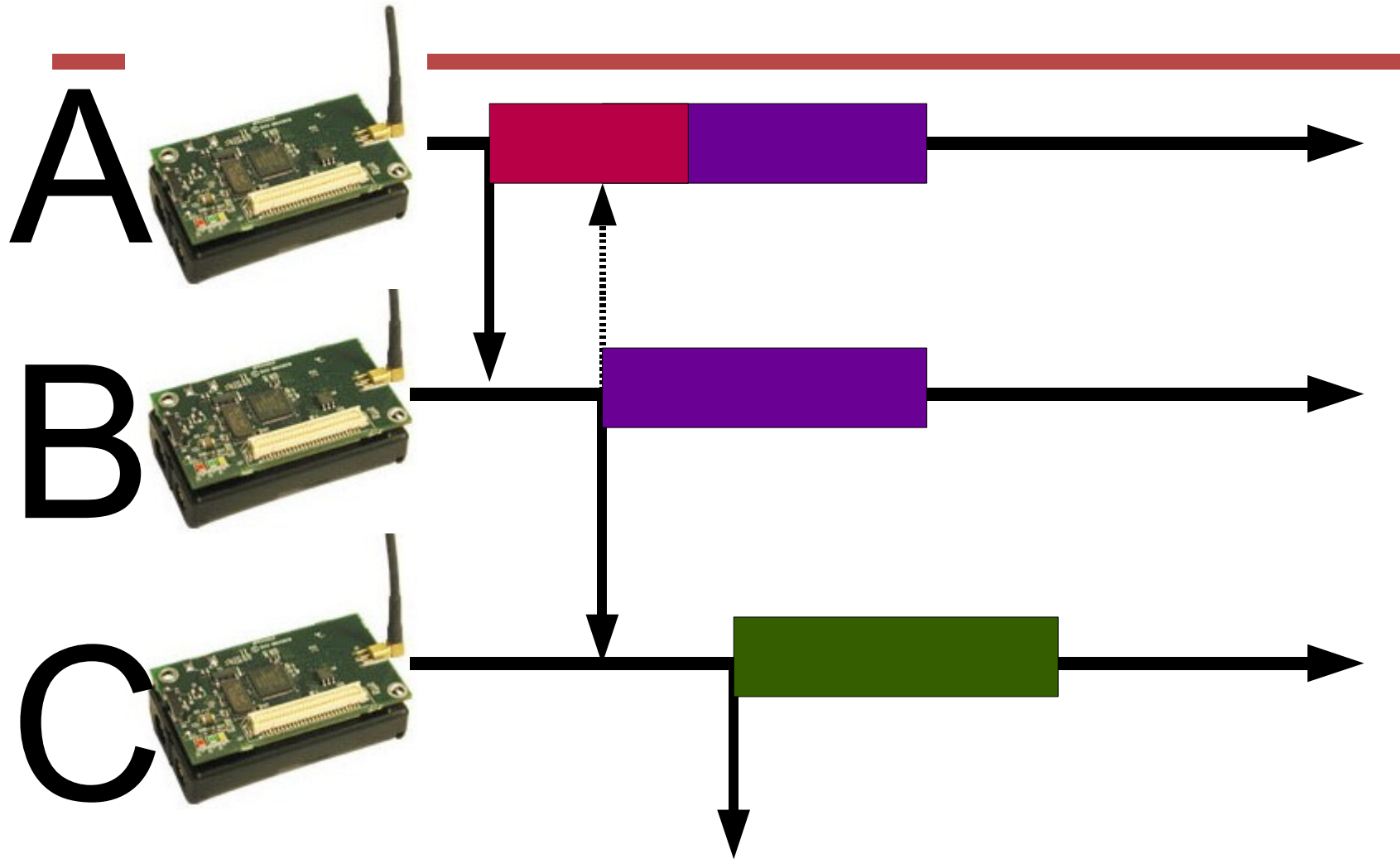
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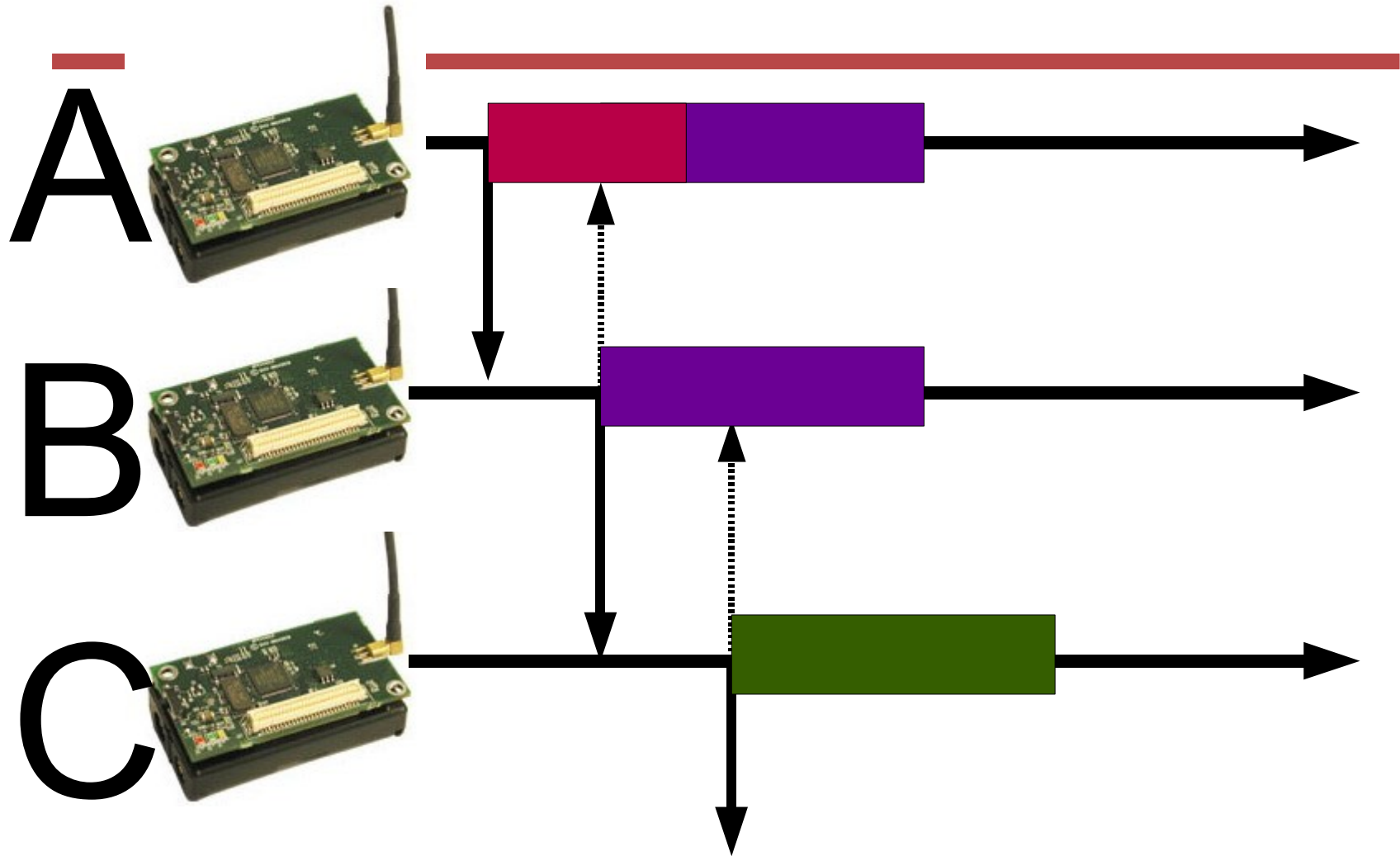
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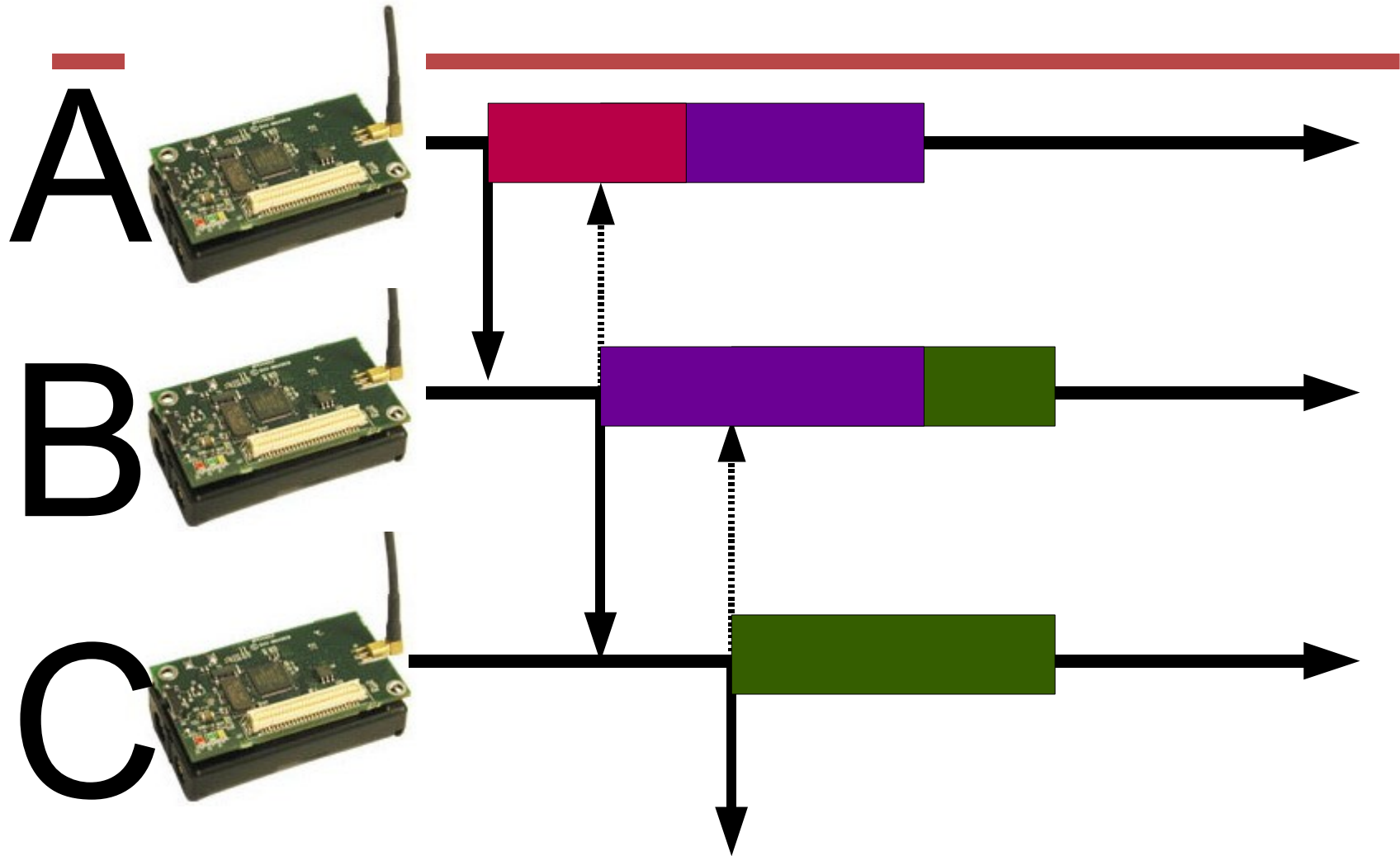
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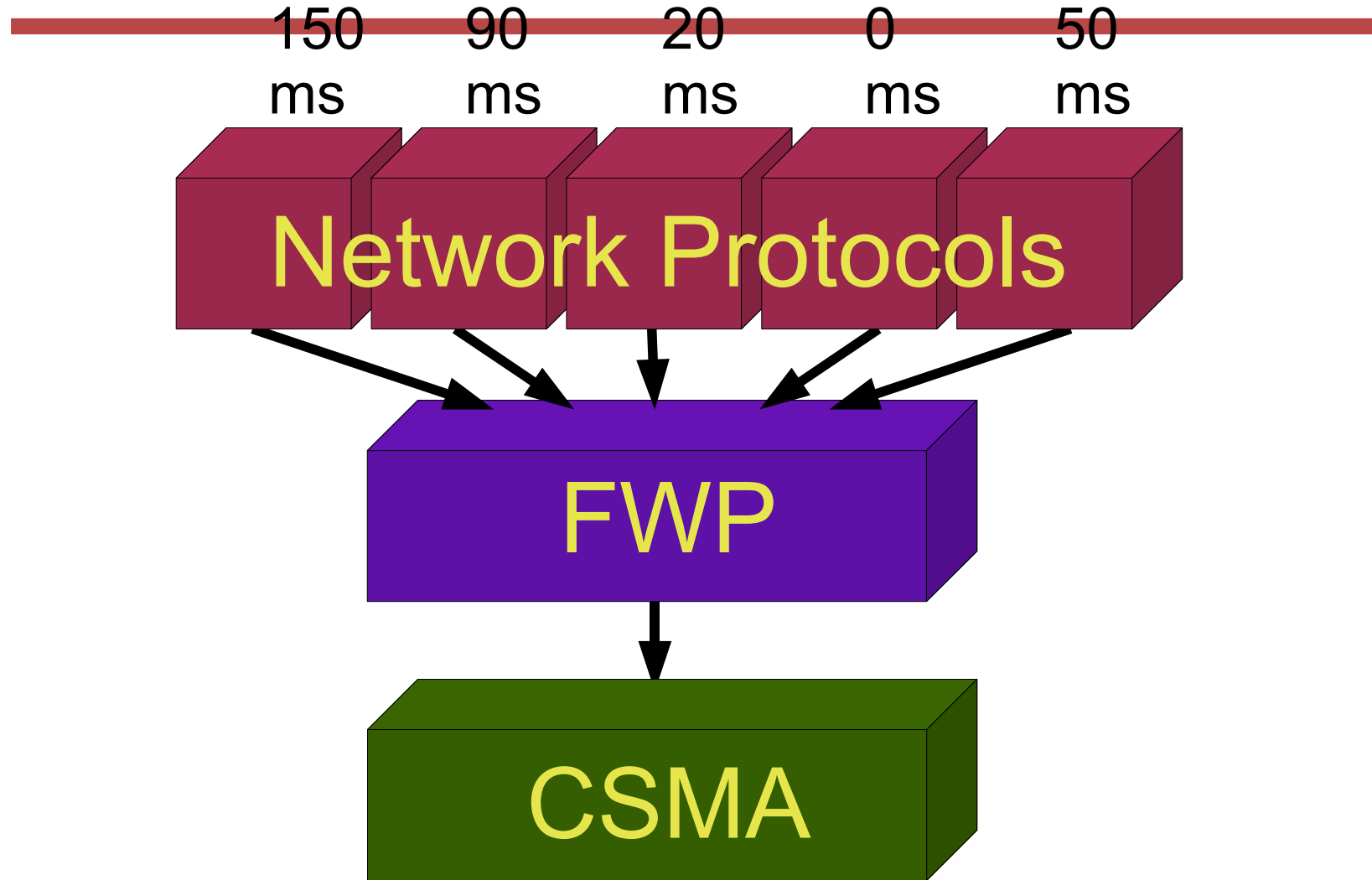
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FWP Fairness



FWP Isolation

