Stream: Low Overhead Wireless Reprogramming for Sensor Networks

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Ontline

- Introduction
- Existing protocol: Deluge
- Stream design
- Stream analysis
- Experiments and result
- Conclusion

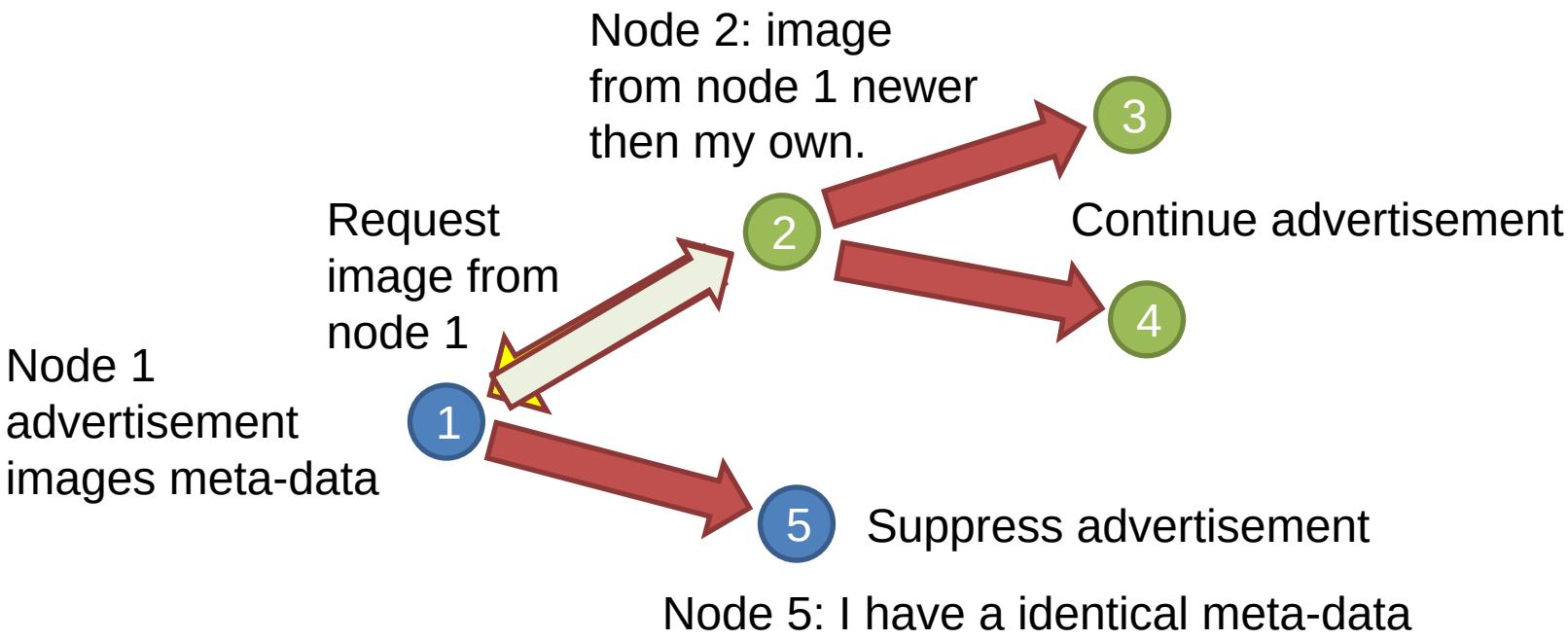
Introduction

- Existing protocol bundling the reprogramming protocol and application as one program image
- Stream: to minimize the size of the part which is need to bound with application.

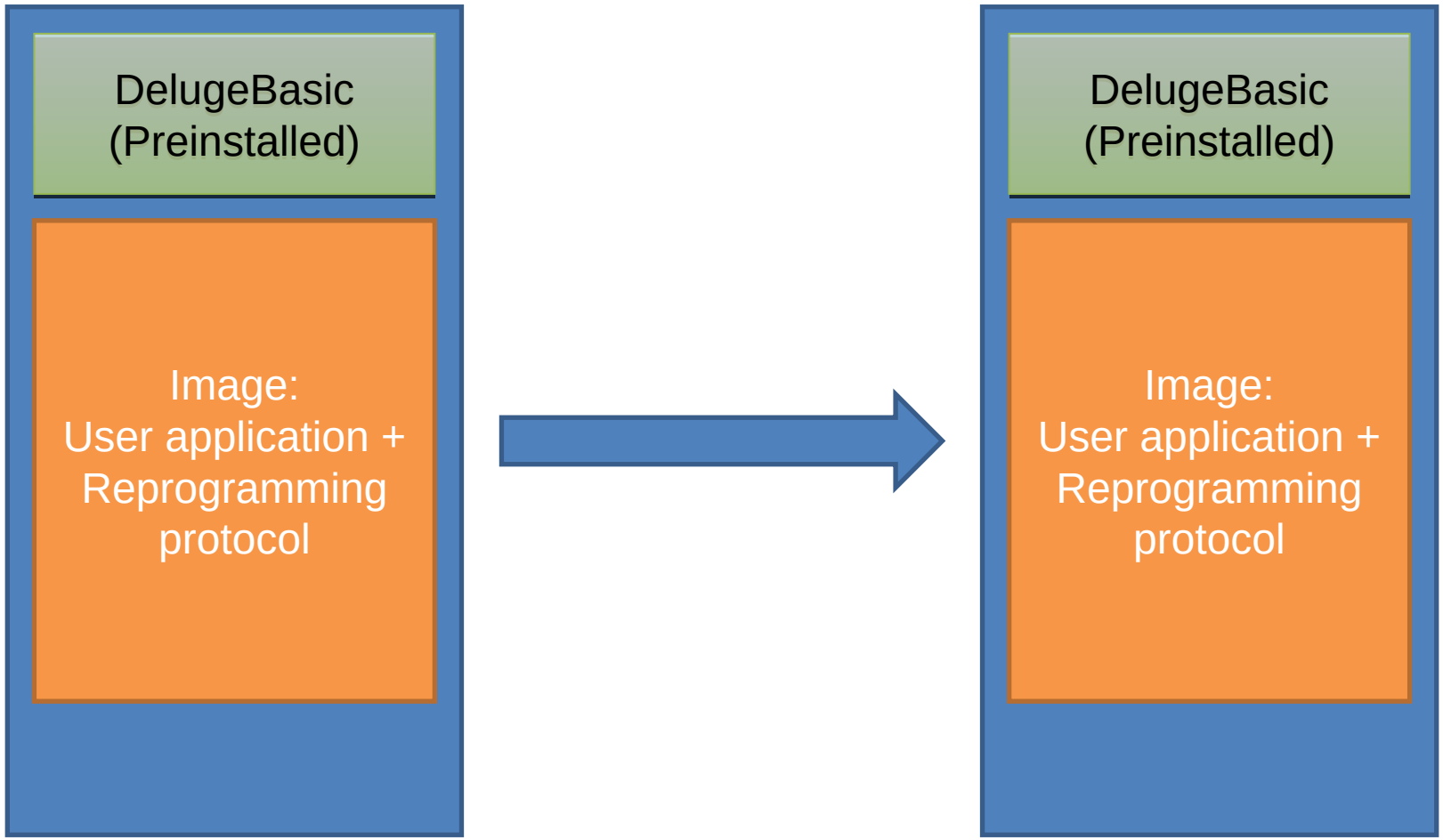
Deluge

- Using monotonically increase version number for images.
- Segments the binary code image into pages, and pipelines the different pages across the network.
- Three-way handshake: advertisement, request, broadcast.

Deluge


Node 2: image
from node 1 newer
then my own.
3
Request
image from
node 1
2
Continue advertisement
4
Node 1
advertisement
images meta-data
1
5
Suppress advertisement
Node 5: I have a identical meta-data

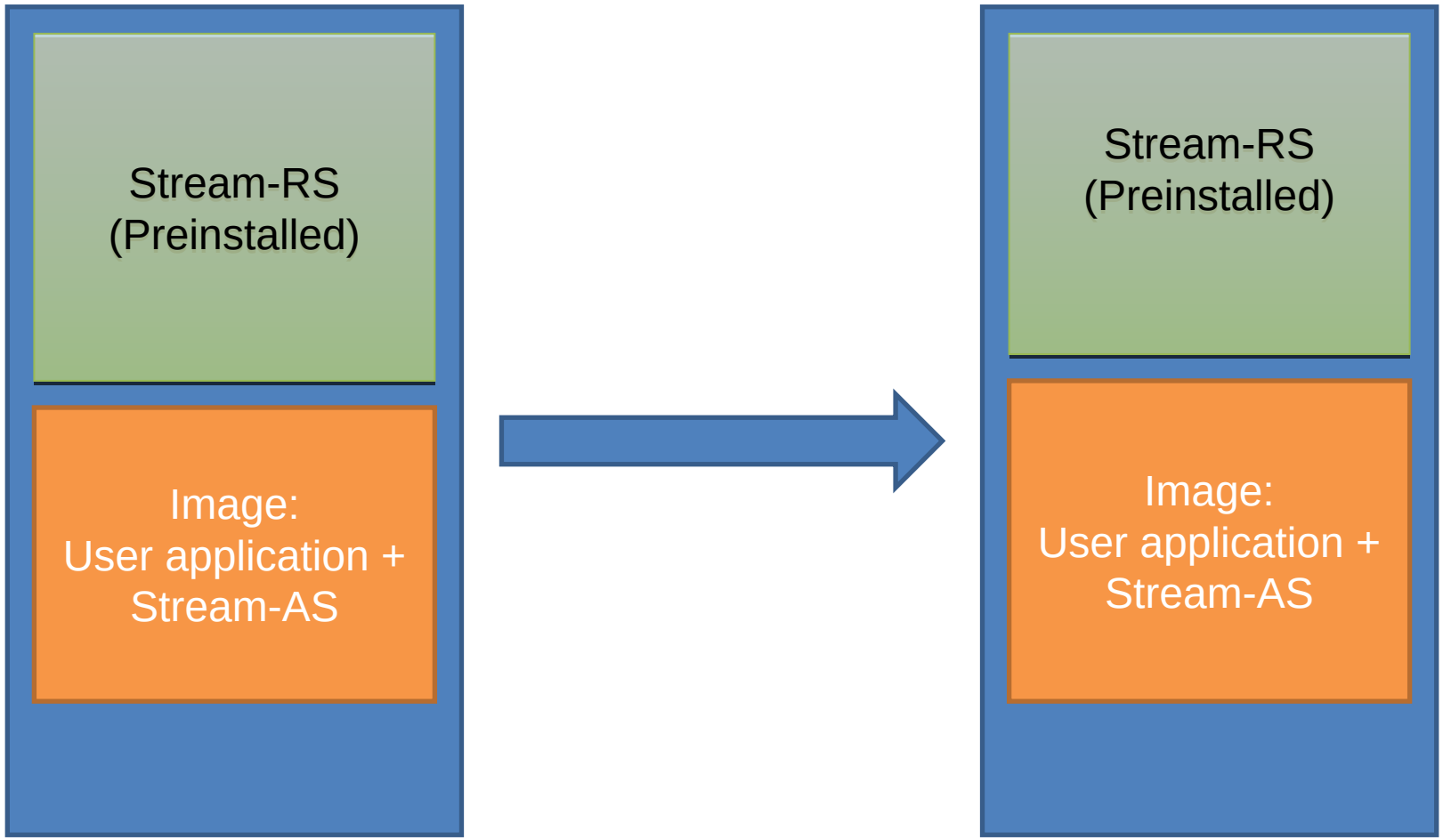
Deluge – Transmitting Images



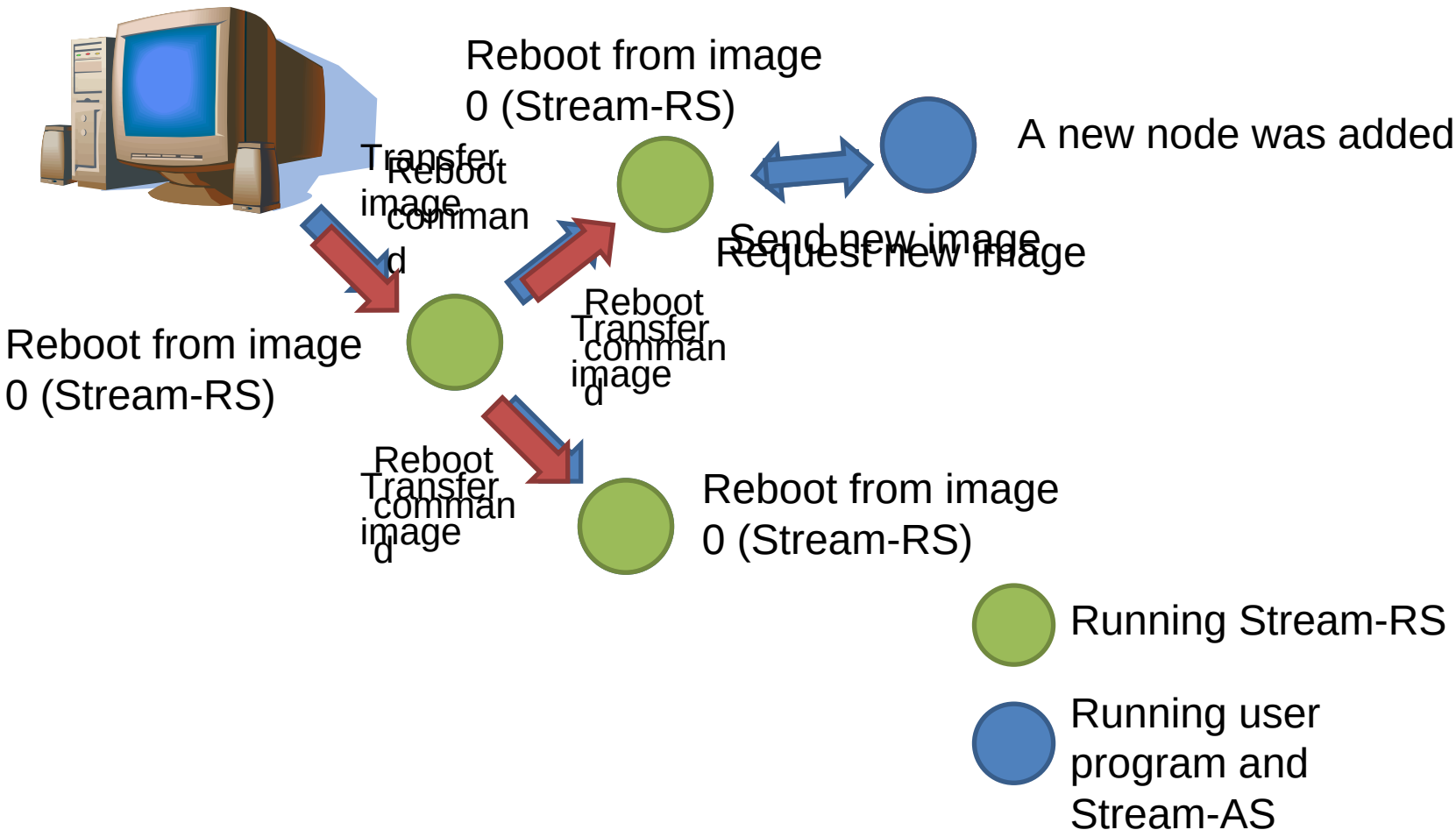
Stream Design

- StreamReprogrammingSupport(Stream-RS) as image 0.
- StreamApplicationSupport(Stream-AS) attached to user’s application.
- Only transfer user application and Stream-AS
- Stream-AS provides a little reprogrammimg functionality of reprogramming protocol.

Stream – Transmitting Images



Stream: Protocol design



Stream-AS

- Attached to user application
- Provide the functionality to reboot from image 0

Stream-AS

- Like Deluge, two lines of nesC code most be added:
  - Components StreamASC;
  - Main.StdControl->StreamASC;

Stream-AS

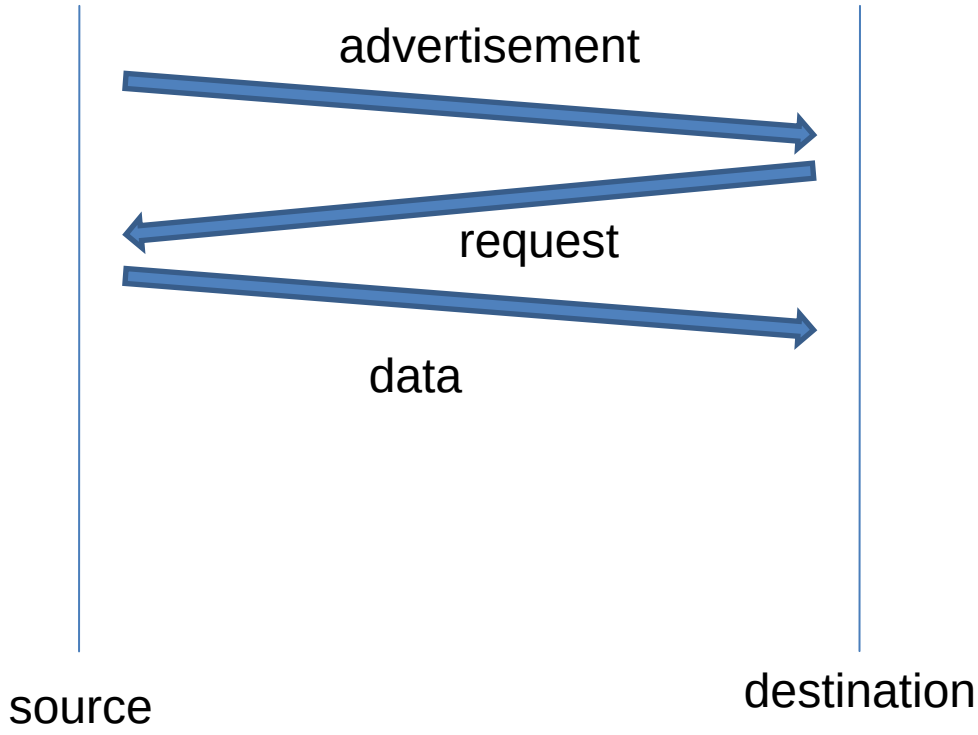
- Steady-state behavior
  - Does not advertise code image meta-data
  - Uses less RAM for Stream than for Deluge

Stream-RS

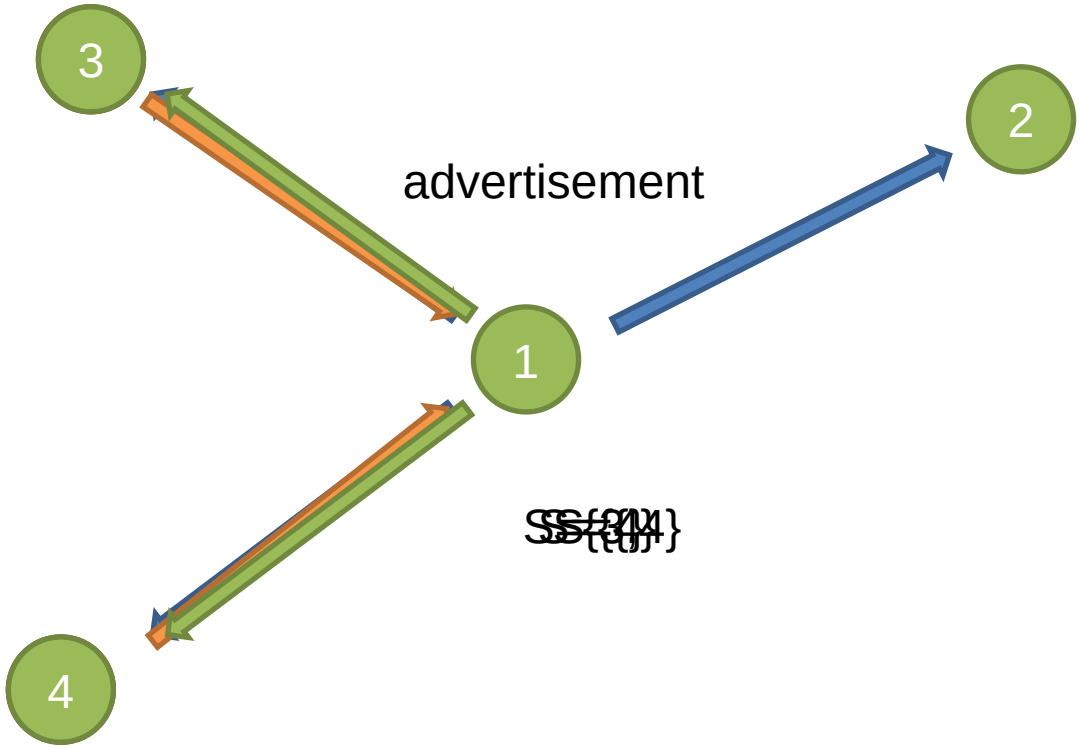
- Preinstalled in all nodes as node 0
- Executed during reprogramming phase
- Transfer image

Stream-RS

- Three-way handshake



Stream-RS



Stream analysis-Energy Cost

- Assume retransmission of packet are independent
- The energy cost of transfer a image to a h hop node

$$E_h = \frac{h \times N_p \times N_{pkt} \times C}{P_s}$$

  - Ps = the probability of successful transmession
  - Np = number of pages
  - Npkt = number of packets in each page
  - C = energy cost of transmitting one packet

Stream analysis-Energy Cost

- For total energy cost

$$E = \sum_{h=1}^{h=h_{\max}} [N_{Nh} \times \frac{h \times N_p \times N_{pkt} \times C}{P_s}]$$

  - N_{Nh} = Number of nodes at hop h

Stream analysis-Energy Cost

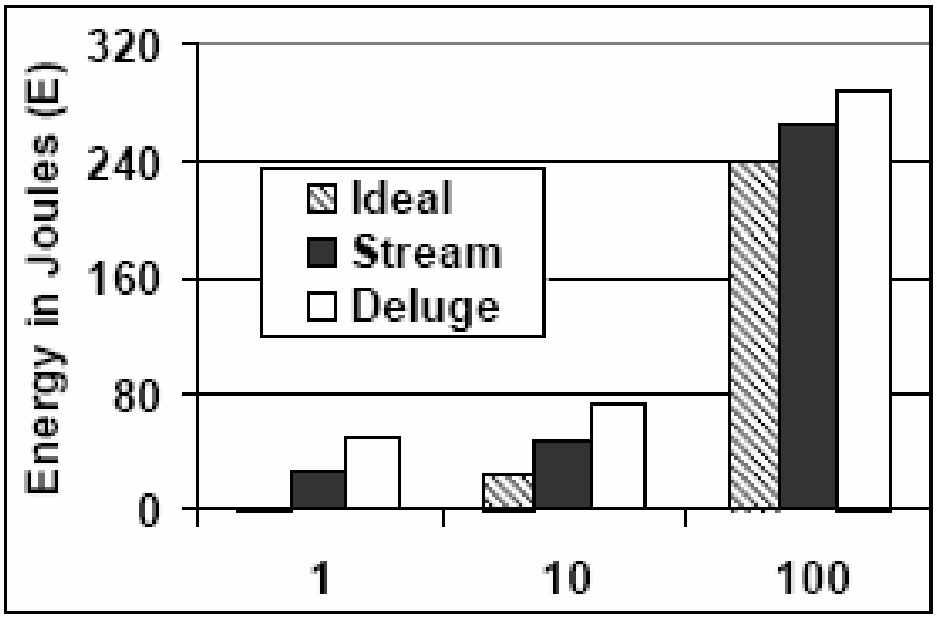


Figure 3: Total energy consumed in the 10×10 grid topology with standalone applications

A standalone application (which does not perform radio communication)

- Deluge: increase 20 page
- Stream: increase 10 pages

Stream analysis-Energy Cost

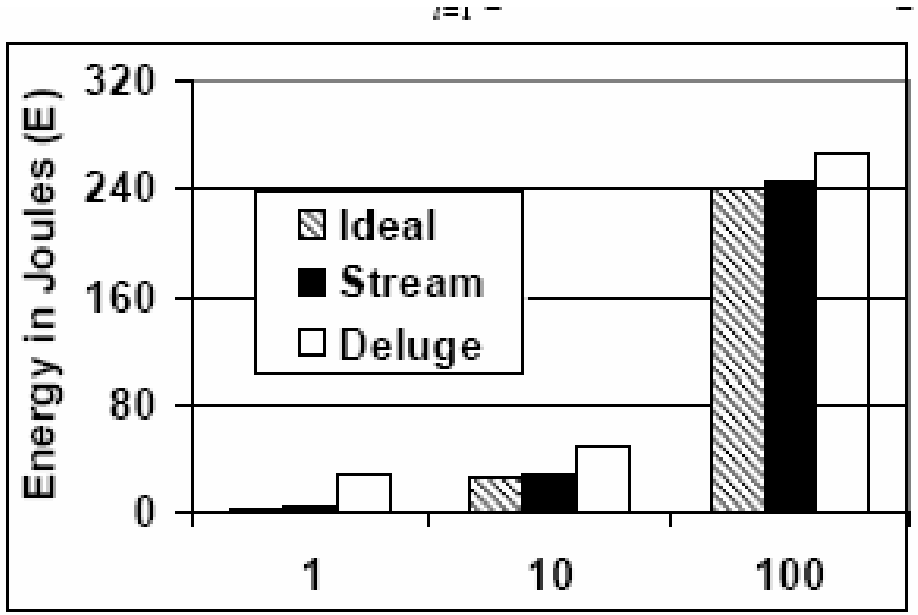


Figure 4: Total energy consumed in the 10×10 grid topology with communicating applications

GenericComm component (provided by TinyOS)

- Deluge: increase 11 page
- Stream: increase 1 pages

Stream analysis-Convergence Time

- The expected convergence time is

$$T_{conv} = T_r \times (N_p + h_{\max} - 1) \times \sum_{i=1}^{\infty} [1 - (1 - (1 - P_s)^{i-1})^{N_{pkt}}]$$

  - T_r = round time
  - $h_{\max}$ = maximum number of hops

Stream analysis-Energy Cost

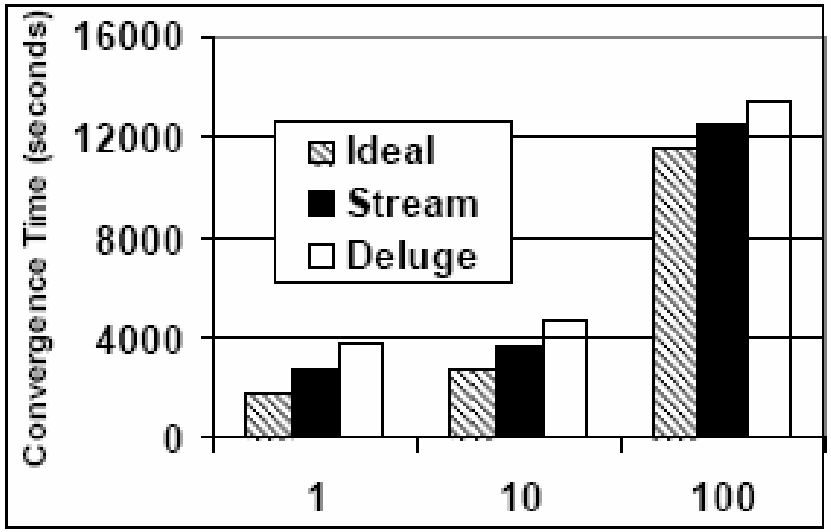


Figure 5: Convergence time for 10×10 grid topology with standalone applications

A standalone application (which does not perform radio communication)

- Deluge: increase 20 page
- Stream: increase 10 pages

Stream analysis-Energy Cost

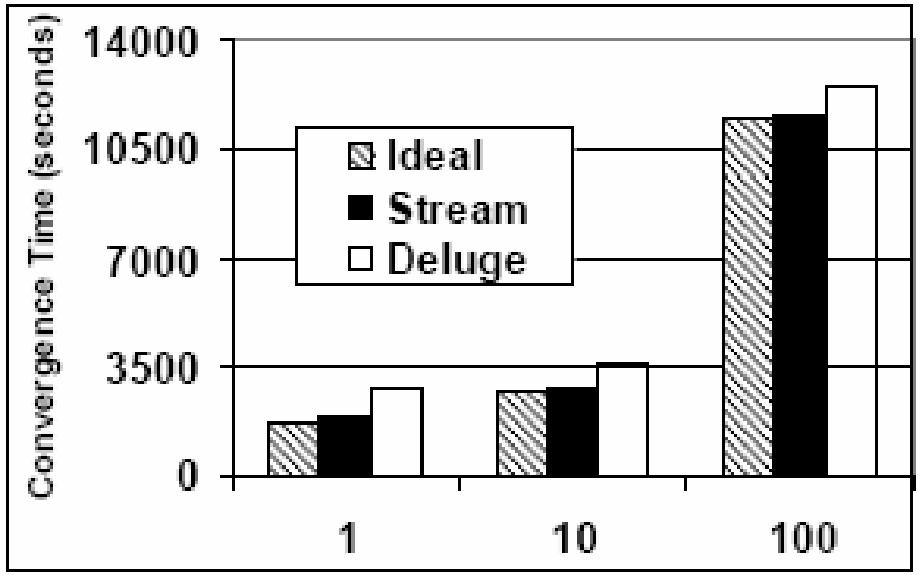


Figure 6: Convergence time for 10×10 grid topology with communicating applications

GenericComm component (provided by TinyOS)

- Deluge: increase 11 page
- Stream: increase 1 pages

Experiments

- Mica2
  - 7.37 MHz, 8-bit microcontroller
  - 128KB program memory
  - 4KB RAM
  - 512KB external flash
  - Communicate via 916MHz radio transceiver
- Topologies:
  - Grid
  - Linear

Experiments - Grid

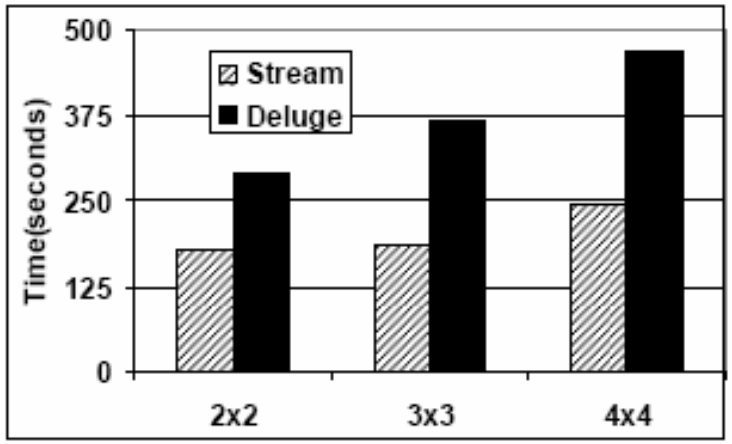


Figure 7: Reprogramming time for grid networks

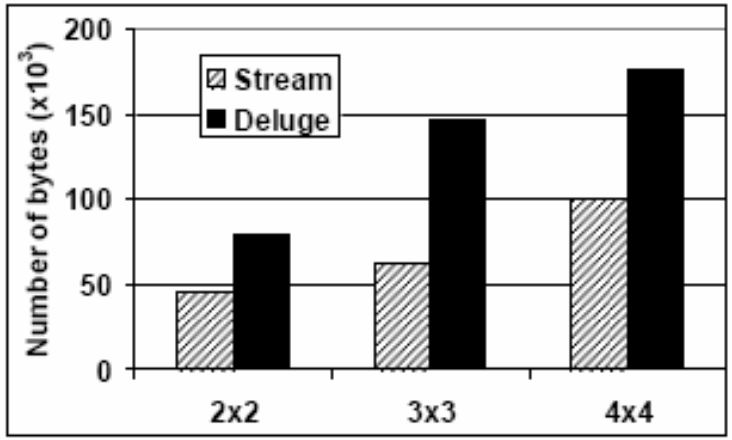


Figure 8: Number of bytes transmitted in the network during reprogramming for grid networks

- Application: 11 pages
- Deluge: add 22 pages
- Stream: add 12 pages

Experiments - Linear

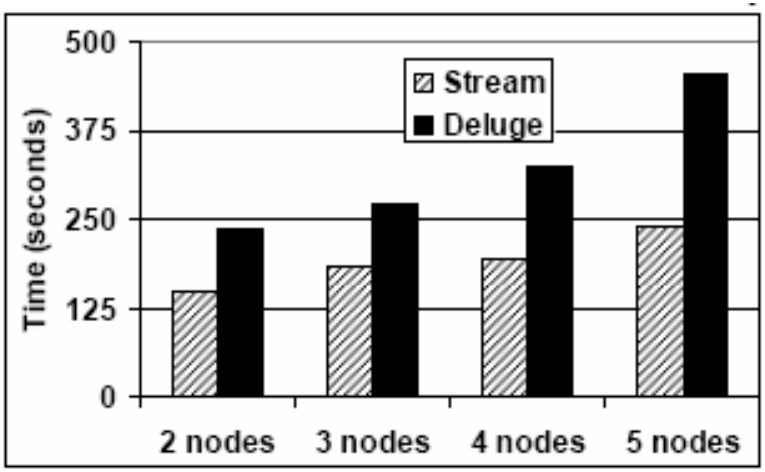


Figure 9: Reprogramming time for linear networks

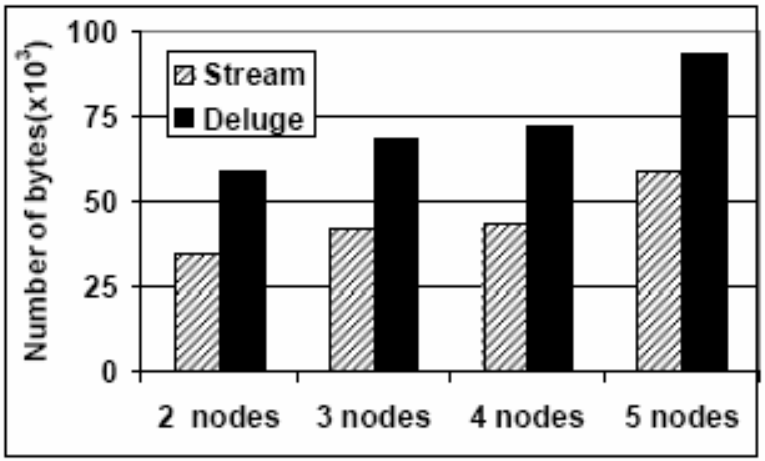


Figure 10: Number of bytes transmitted in the network during reprogramming for linear networks

- Application: 11 pages
- Deluge: add 22 pages
- Stream: add 12 pages

Simulation

- Use TOSSIM
- Larger grid

Simulation

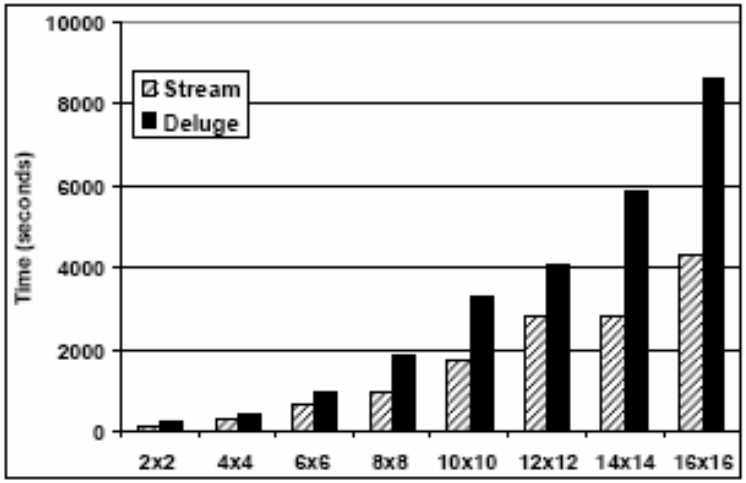


Figure 11: Reprogramming time for nxn grids

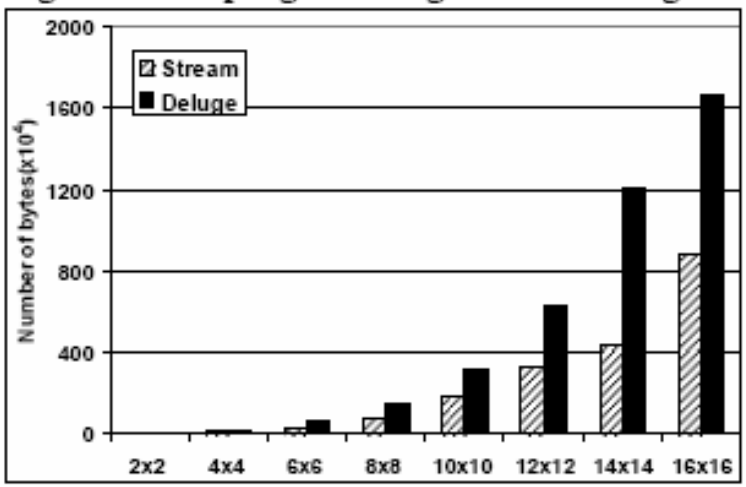


Figure 12: Number of bytes transmitted in the network during reprogramming for nxn grids

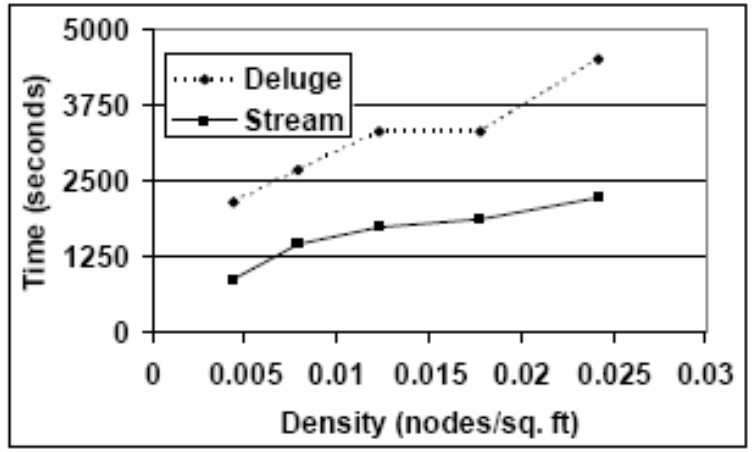


Figure 13: Reprogramming time (different node densities)

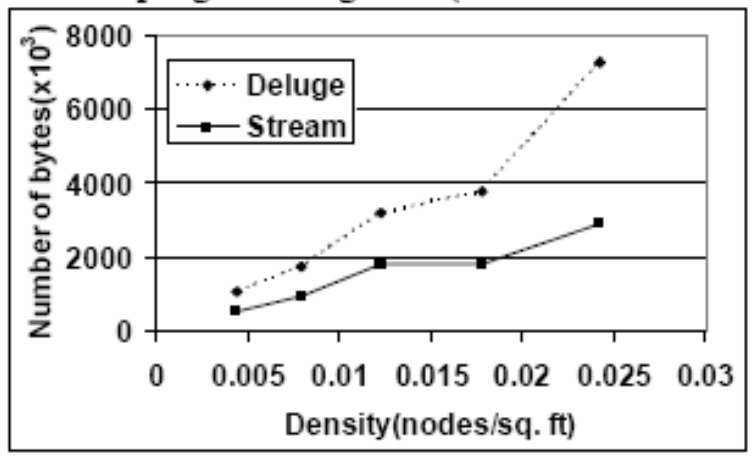


Figure 14: Number of bytes transmitted in the network during reprogramming for different node densities

Conclusion

- Reduce transmitted bit
- Reduce programming time, energy costs and program memory
- Improve the protocol for a new node to get image from network