Distributed Computation in Wireless Ad Hoc Grid Formations with Bandwidth Control

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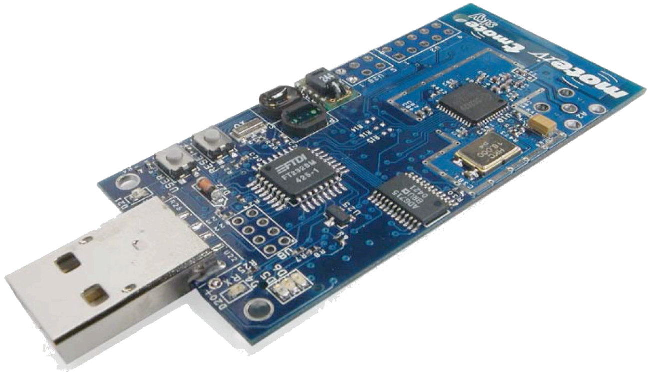
Overview

- Scenario
- Assumptions
- Challenges
- Research Problem
- Approach to Solution
- Experimental Results
- Conclusion
- Future Work

Emergency Scenario

- Emergency ‘CBRE’ events
- Indoor environment (e.g., building or highly frequented public space)
- Hazardous for the first responders to explore the contaminated area
- Need for fast environmental information gathering for C^2

Why Sensors?

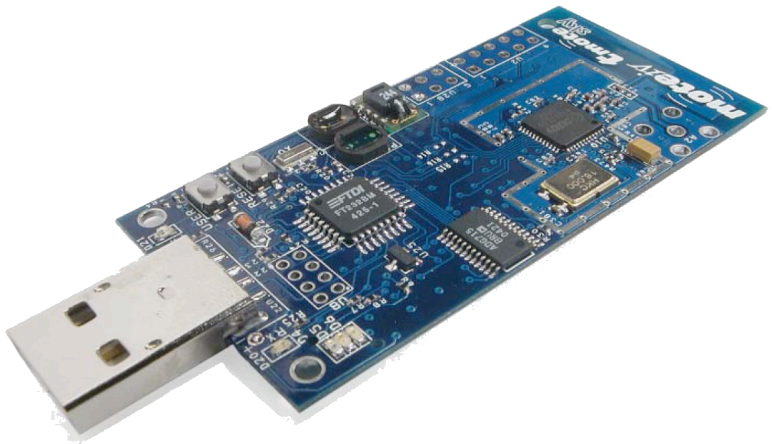


- Cheap devices
- Easily deployable
- Capable of working in hazardous environments
- Standard development platform in the research community
- Even with the availability of more computational capable devices, it is still worth thinking about an infrastructure for the distribution of the computation (it is easy to find applications that exceed the global capacity of every single node)

TMote Sky devices

- Sensor characteristics:
- limited battery power
- small storage capacity

(i.e., 10kB RAM, 48kB Flash ROM)

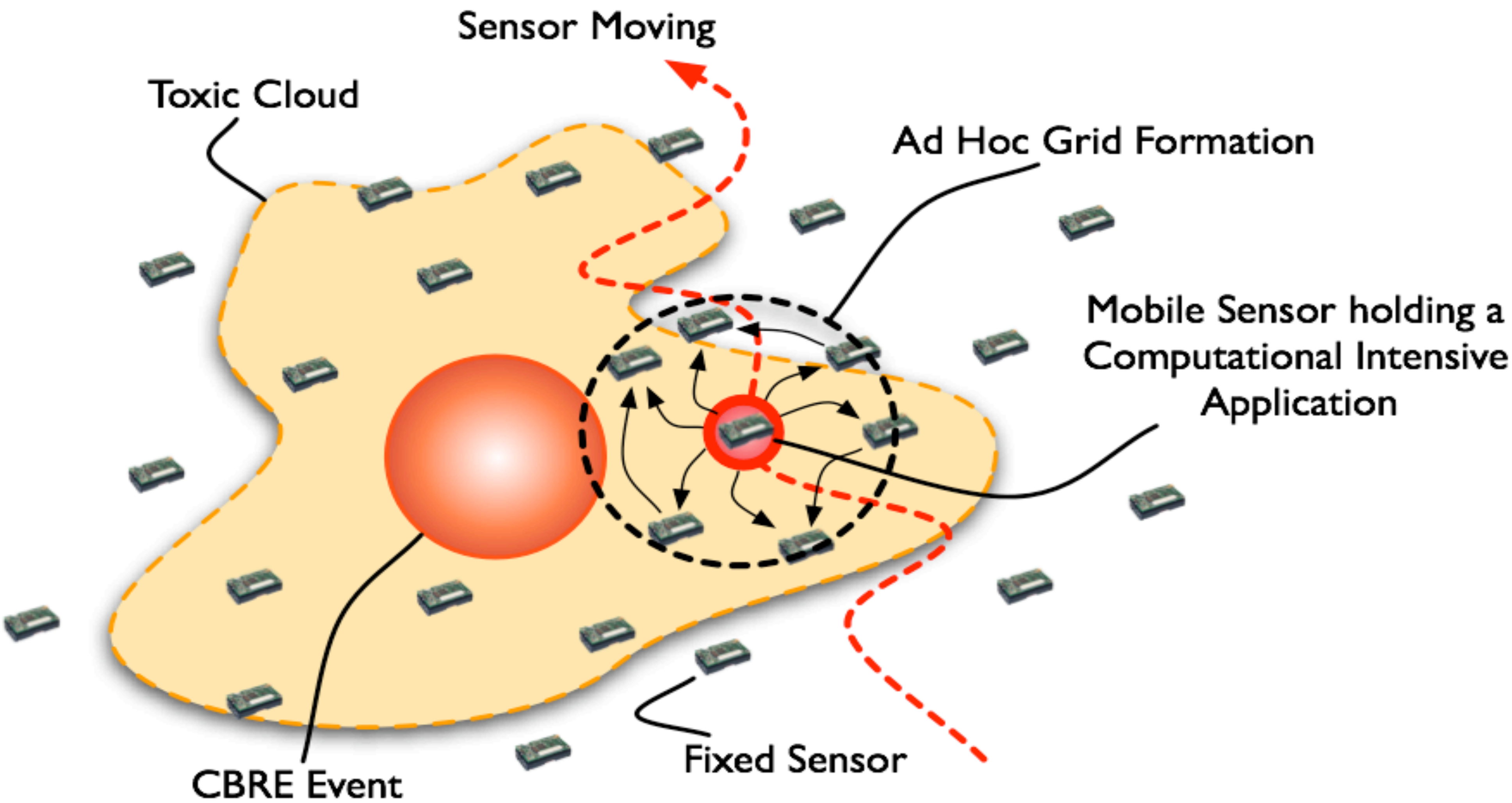


- low computational power

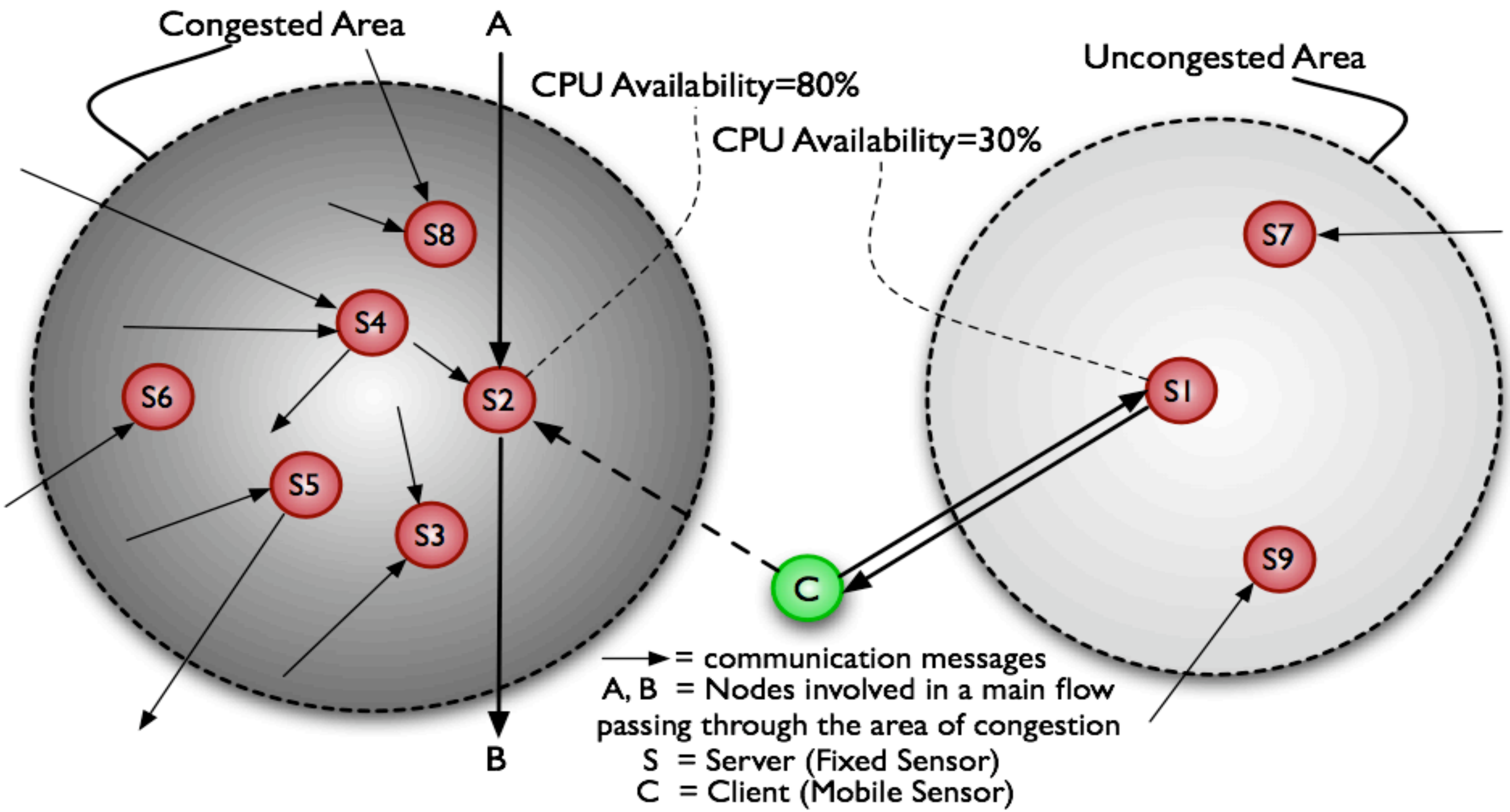
(i.e., MSP430 16-bit microcontroller)

- limited communication capabilities (i.e., CC2420 radio module supporting IEEE 802.15.4, 250kbps as maximum available bandwidth)
- sensing capacity (i.e., humidity, light and temperature sensors are supported by the platform - with the ability to interface more)

(1) Ad Hoc Grid Formation



(2) The Bandwidth Problem



Existing Work Limitations

- They do not take into account communication issues
- They are implemented in simulation environments:
- In simulators, radio communication model are oversimplified
- The implicit difficulties of real-world applications are not met
- They often use a simplistic model of energy-efficiency as metric (instead of latency)

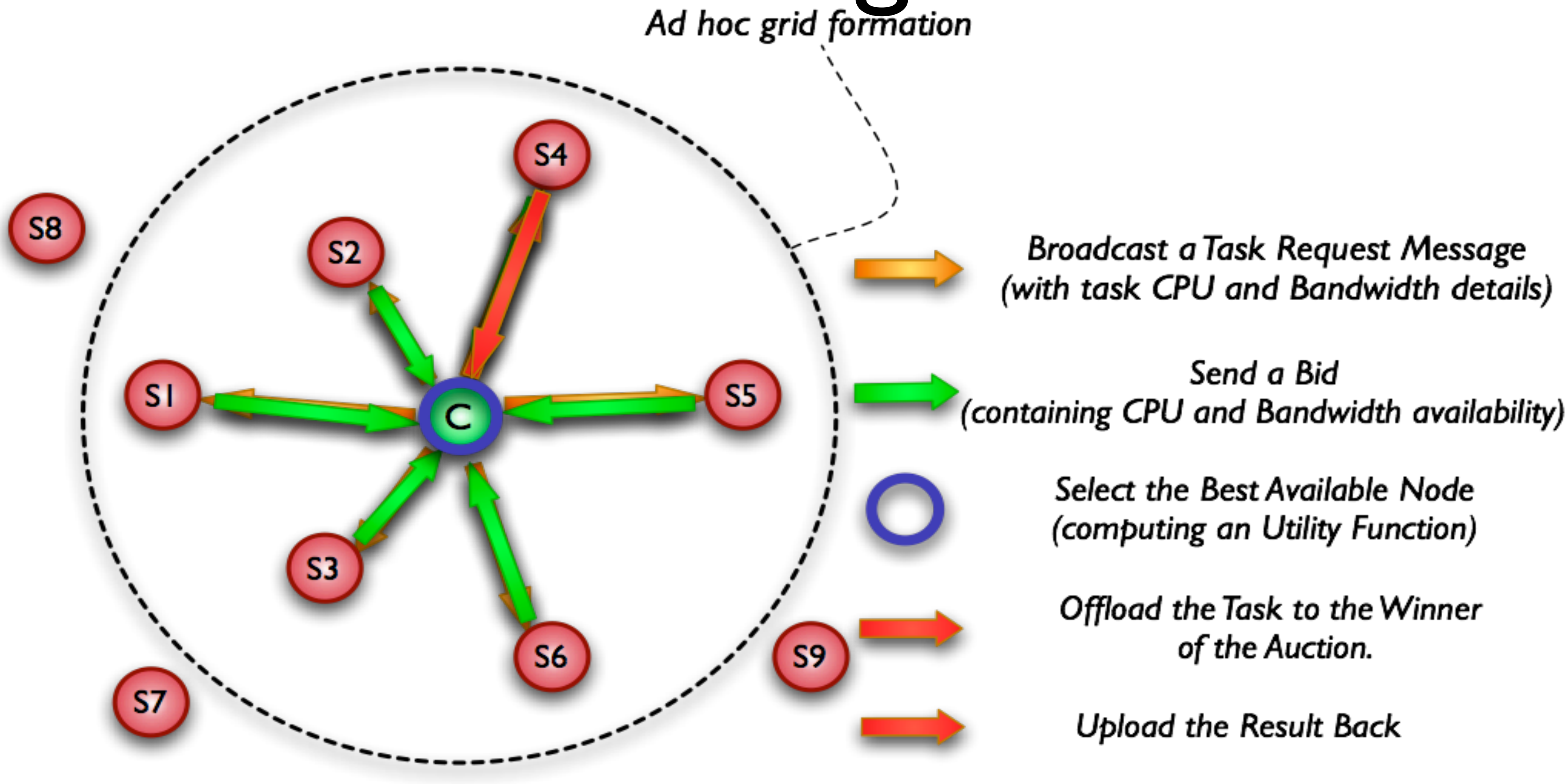
Research Problem

Explore the convergence of
ad hoc sensor networking and that of *computational grids*, presenting novel paradigms that take into account both the computational capabilities of the nodes (CPU) and the local network conditions (bandwidth) when distributing computation.

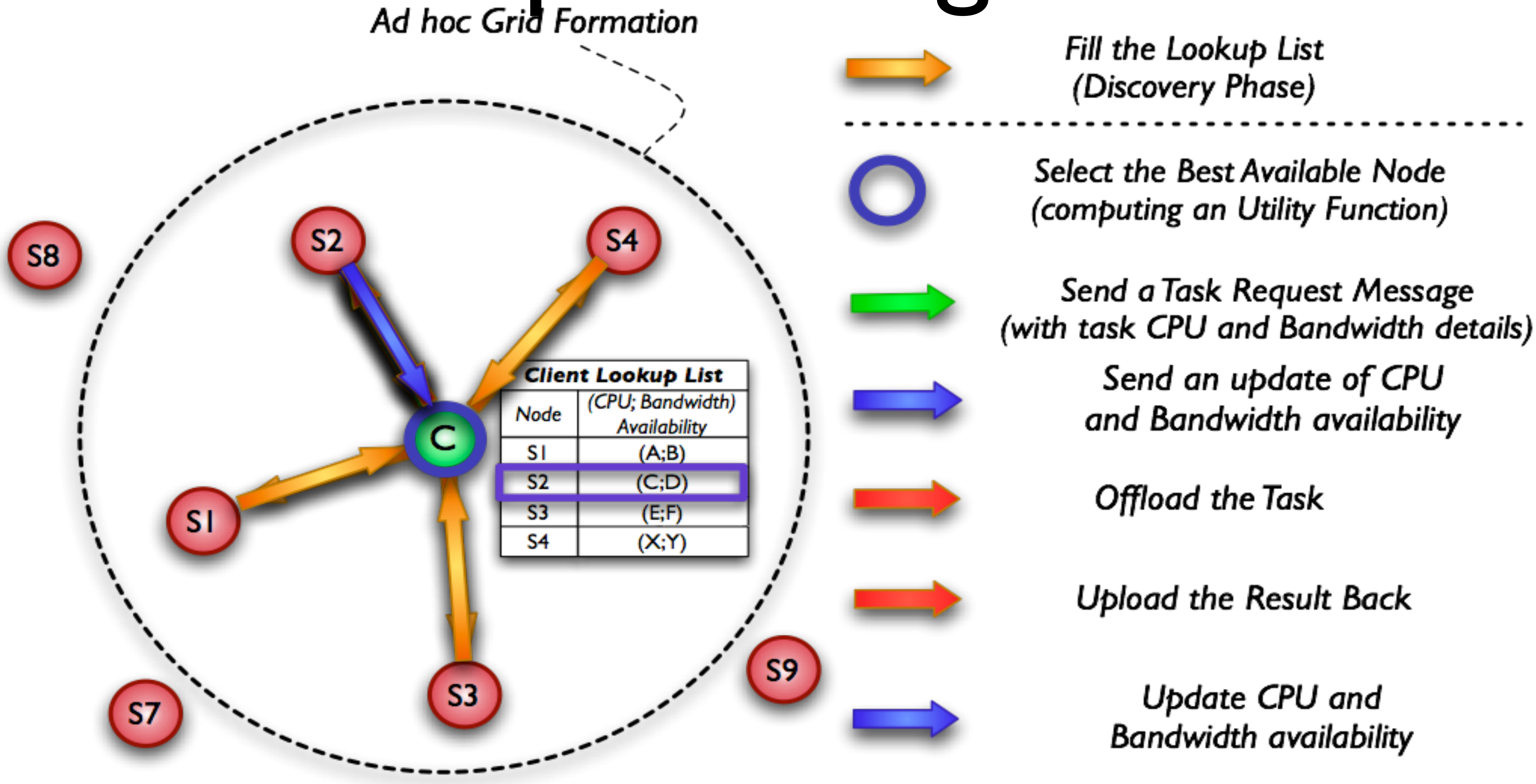
Initial Approach

- We selected two load sharing algorithms (Auction and Lookup List)
- We adapted them to take into account not only *CPU* but also *Bandwidth* requirements during the decisional process
- We implemented them on a sensor testbed
- We used a performance evaluation measuring the average *latency*

Auction Algorithm



Lookup List Algorithm



*P. J. Chuang, C. W. Cheng. On File and Task Placements and Dynamic Load Balancing in Distributed Systems. *Tamkang Journal of Science and Software Engineering* 2002.

Utility Function

Parameters:

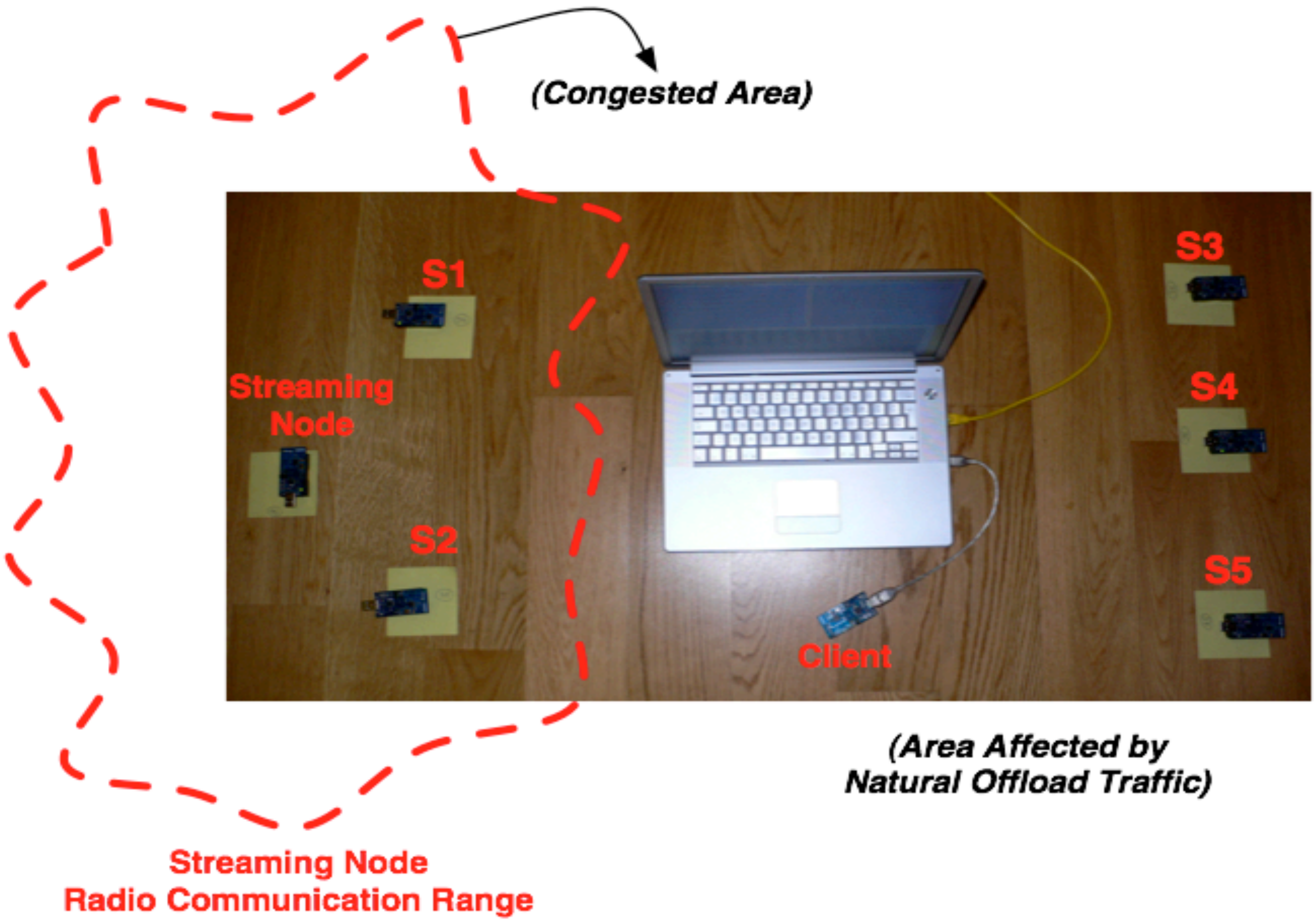
- i = neighbour of a Client ($i=1, ..., N$)
- N = number of a client neighbours
- $C(i)$ = CPU availability of neighbour i
- $B(i)$ = Bandwidth availability of neighbour i
- $S(i)$ = Score of neighbour i
- w_C = Weight CPU
- w_B = Weight Bandwidth

$$S(i) = w_C * C(i) + w_B * B(i)$$

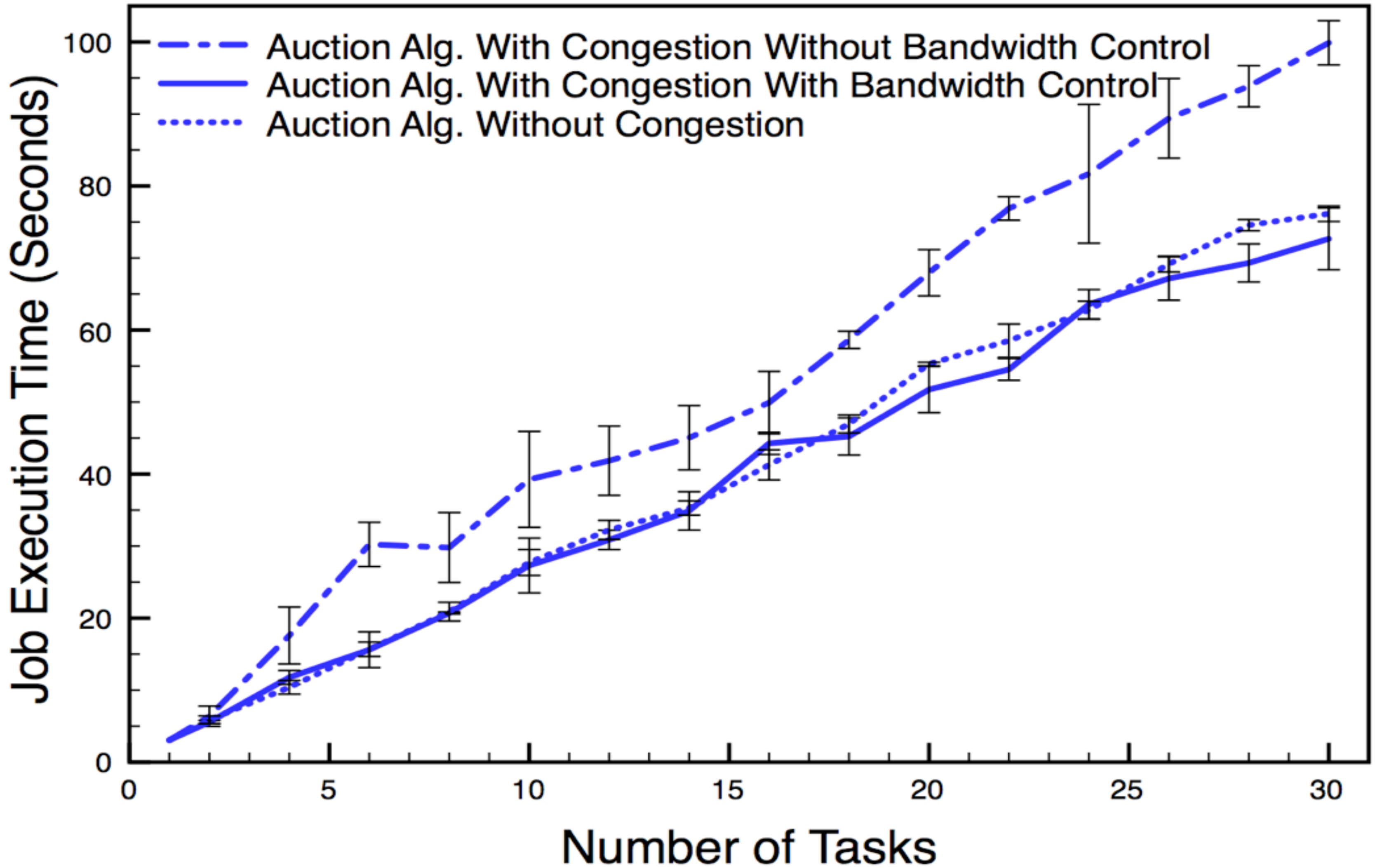
$$\text{Best Candidate} = \max_{i=1, ..., N}\{S(i)\}$$

Small-Scale Testbed

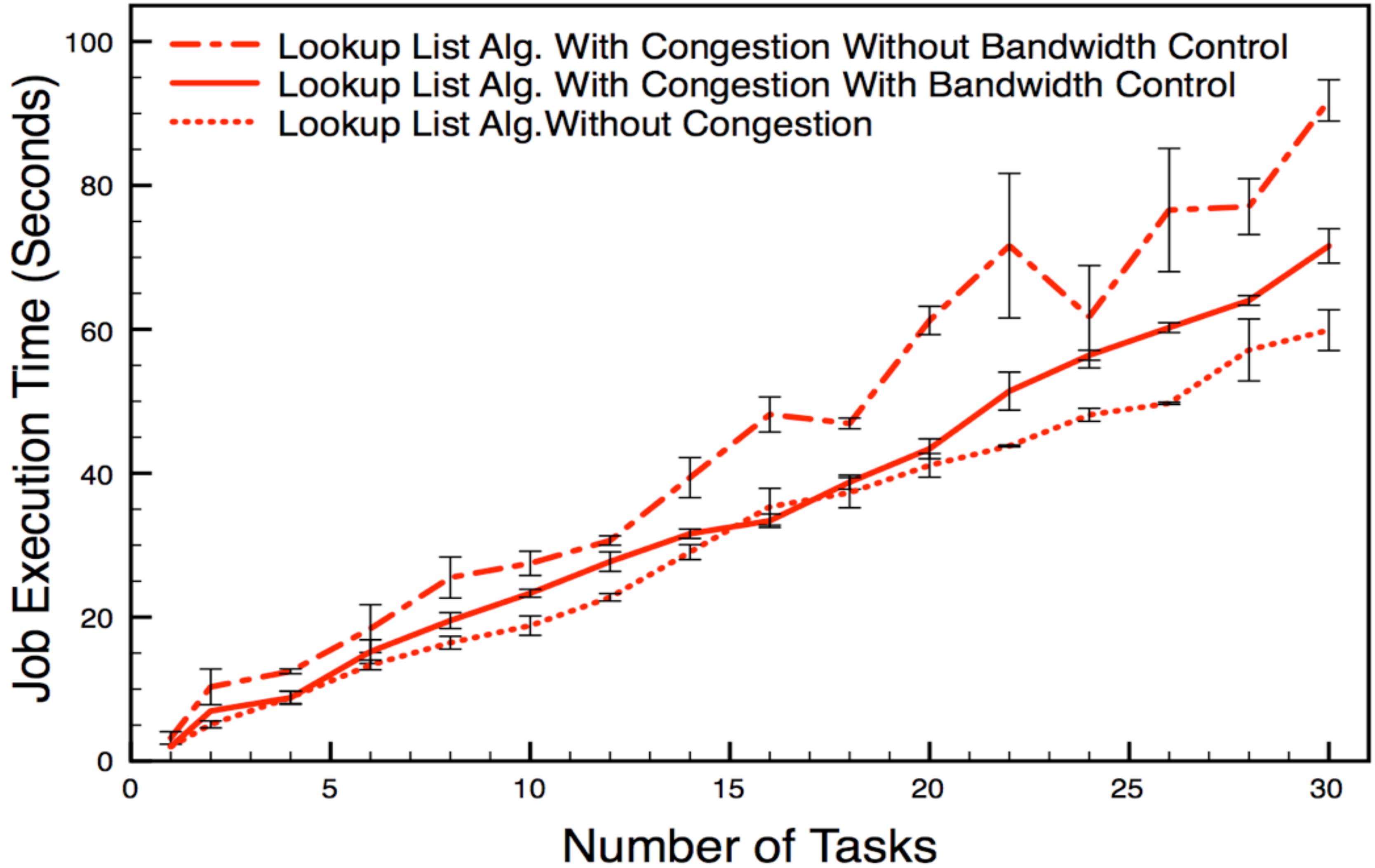
Fixed TMote Sky sensors running the Contiki operating system



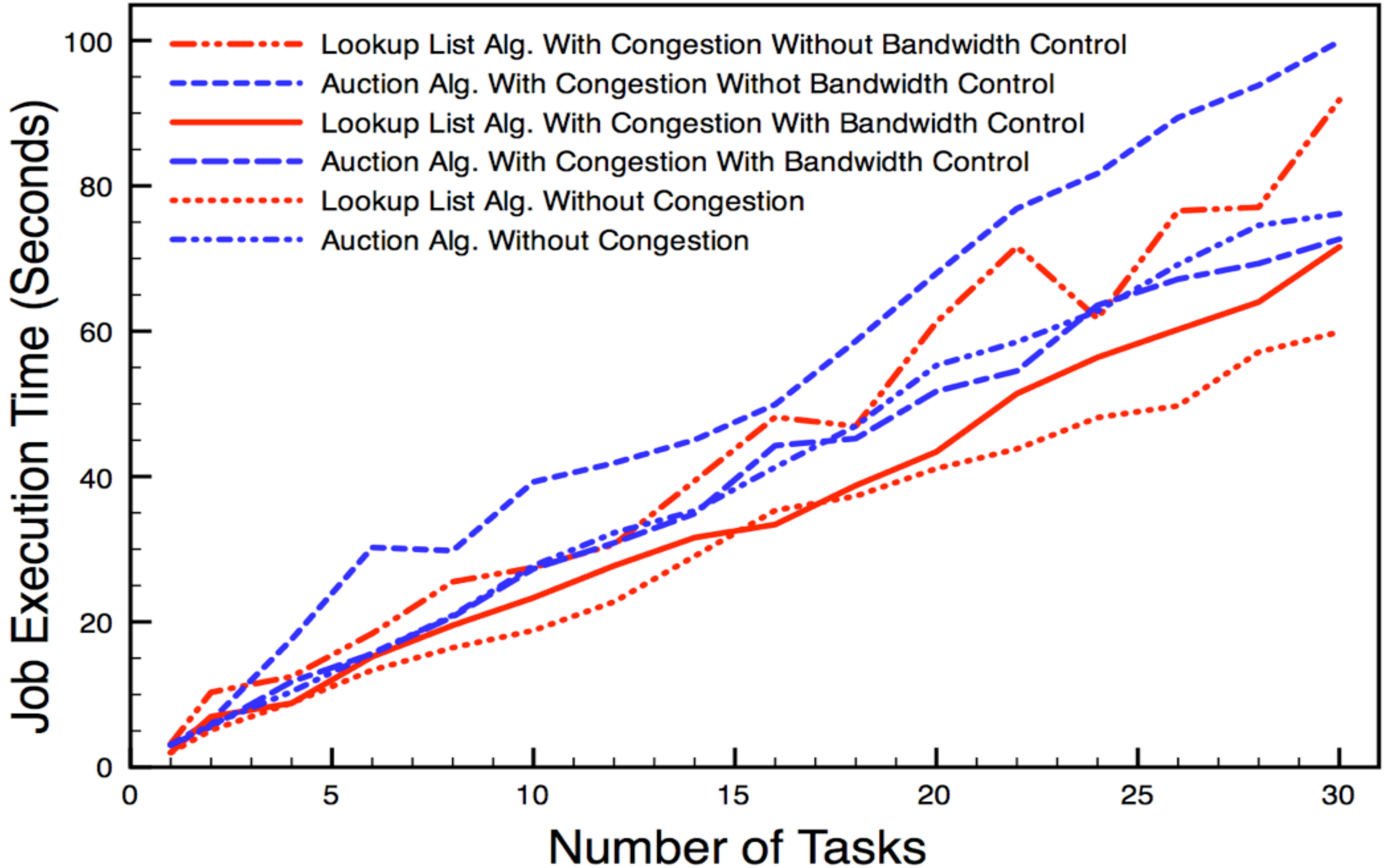
Experimental Results



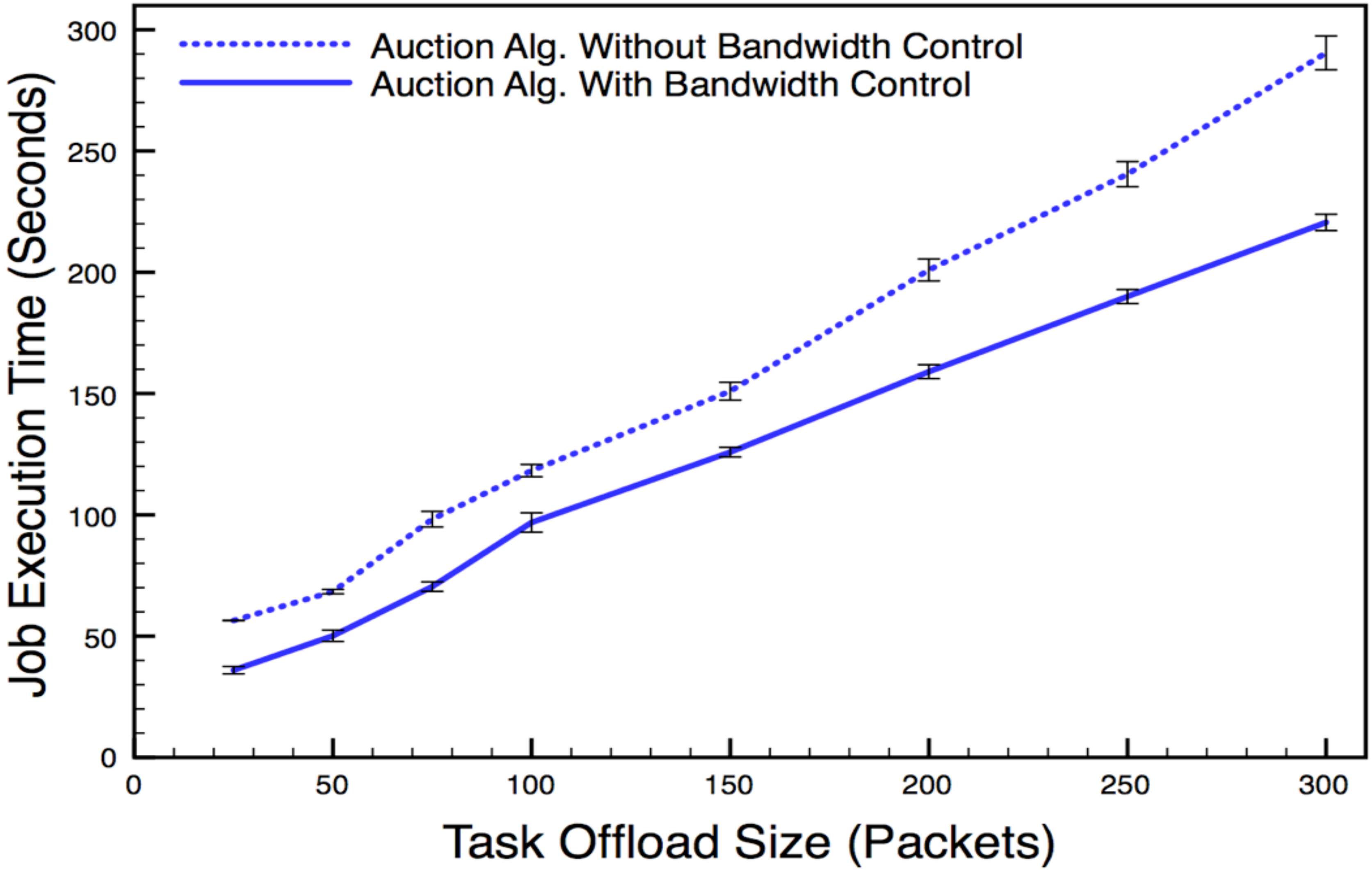
Experimental Results (2)



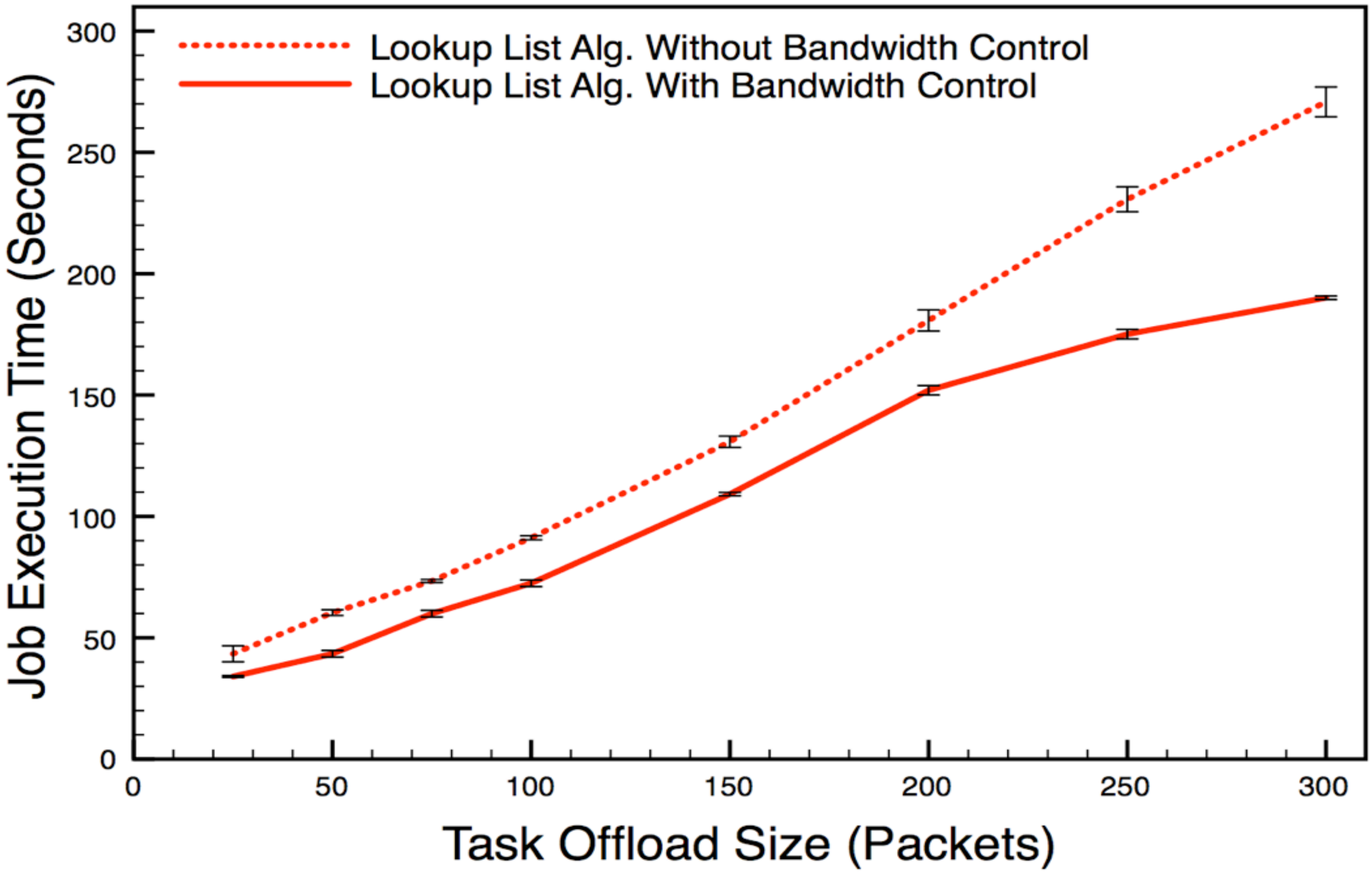
Experimental Results (3)



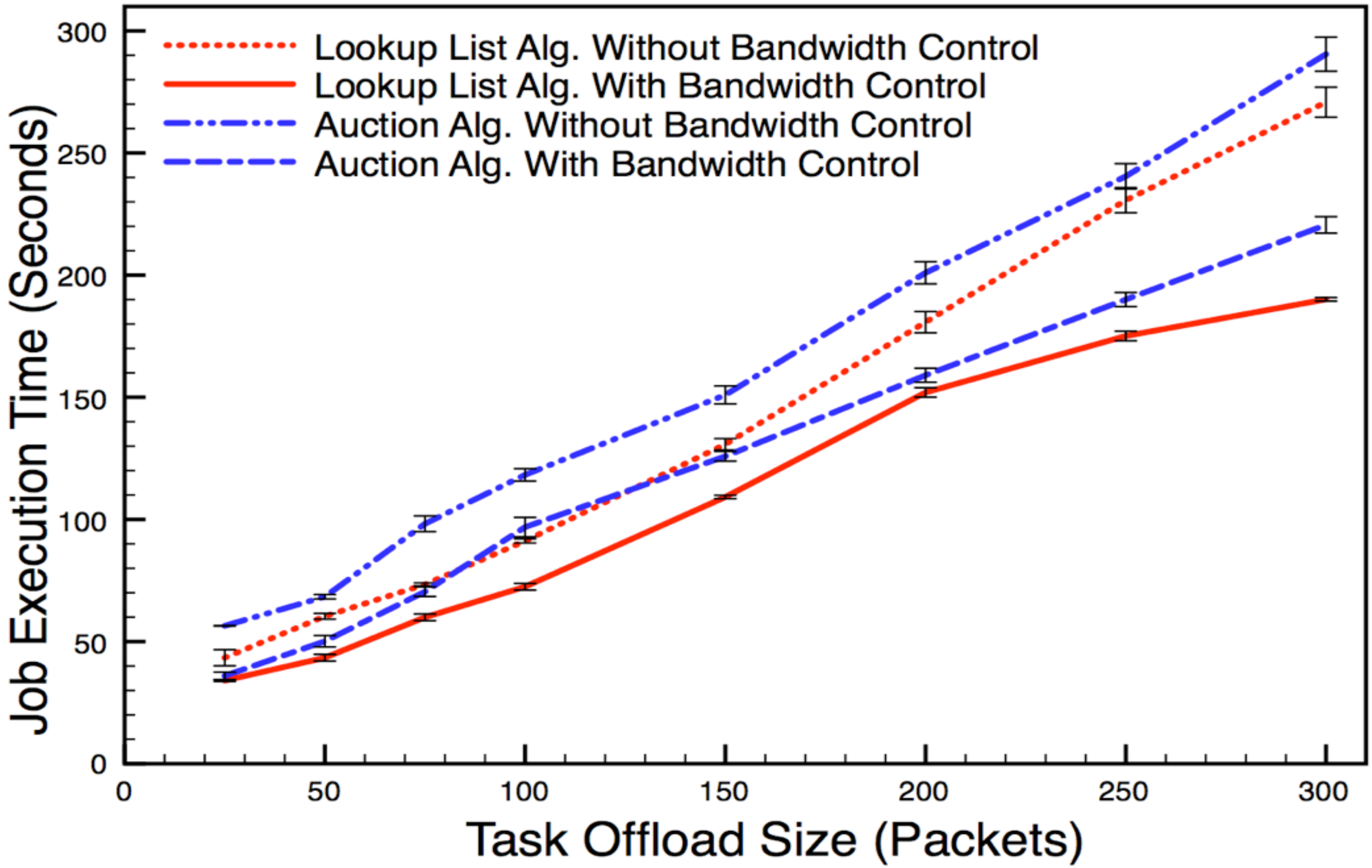
Experimental Results (4)



Experimental Results (5)



Experimental Results (6)



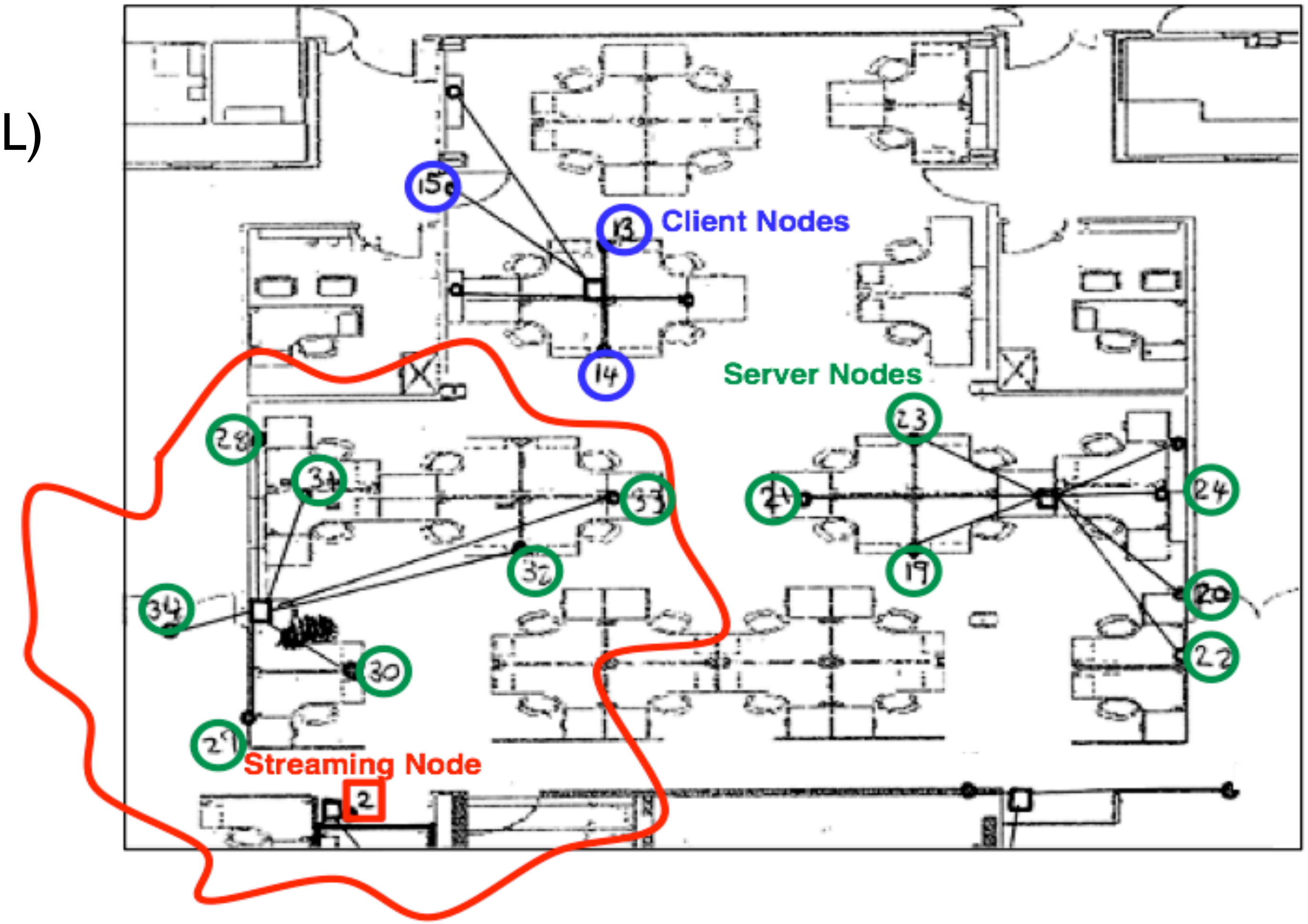
HEN Mote Testbed

http://www.cs.ucl.ac.uk/research/hen/

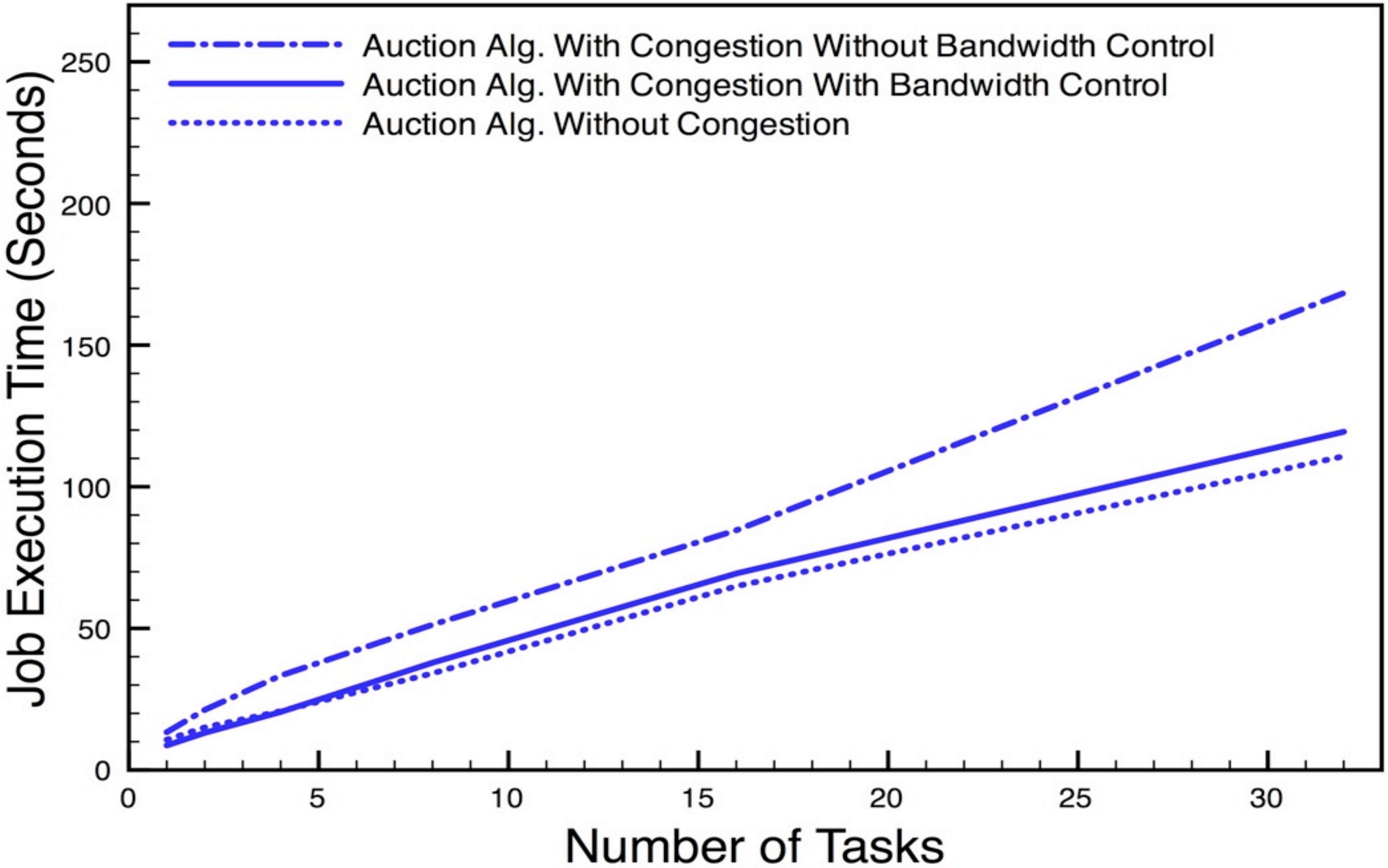
- 40 Tmote Sky Sensors
- Random Deployment
- Remote Accessed
- Remote Programmed
- Fast Kernel Flashing

Large-Scale Testbed - I

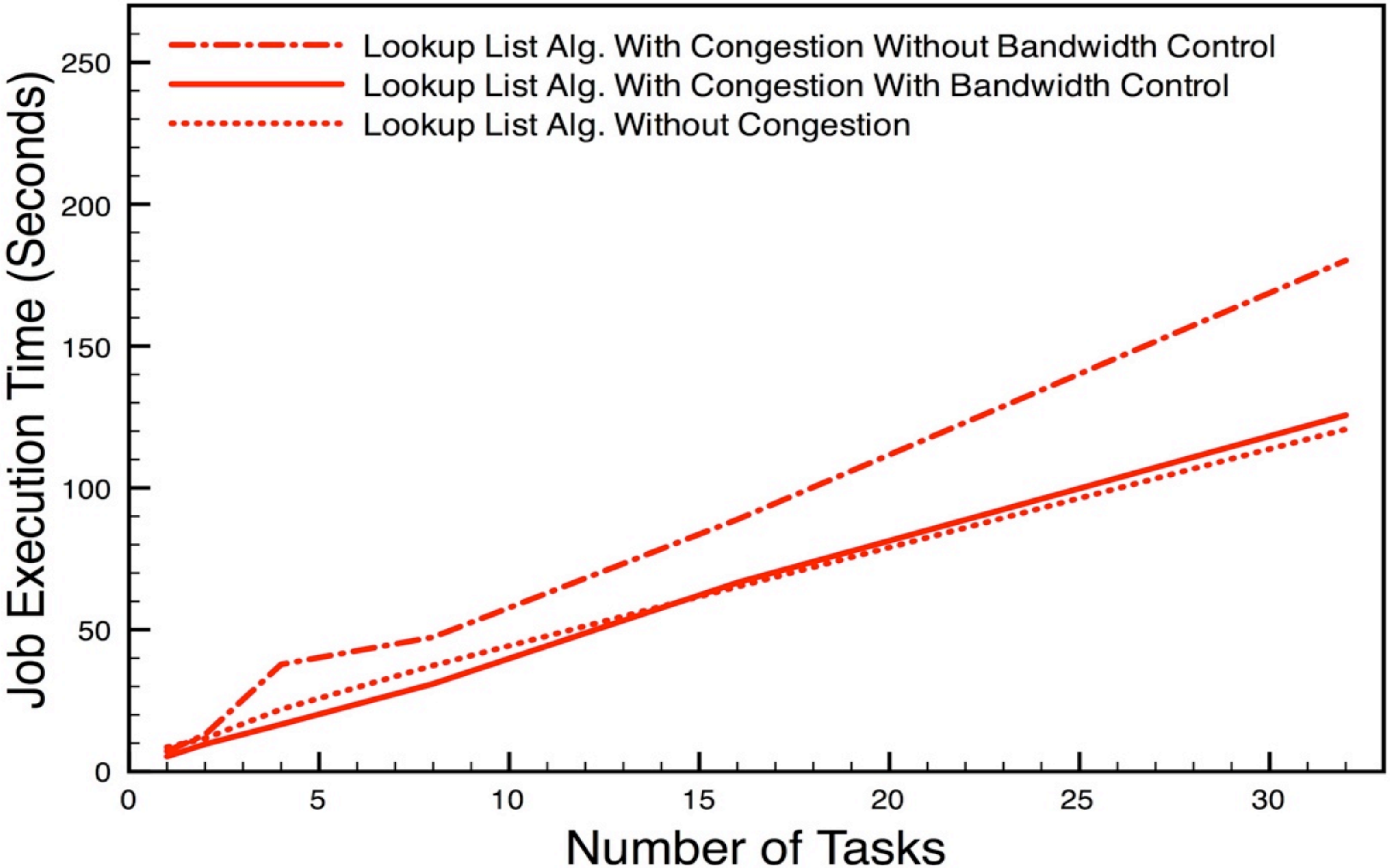
- HEN Mote Testbed (UCL)
- Radio Channel 20
- 32 Tasks Execution
- 50 Offload/Upload Packets
- UDP/TCP Communication



Experimental Results

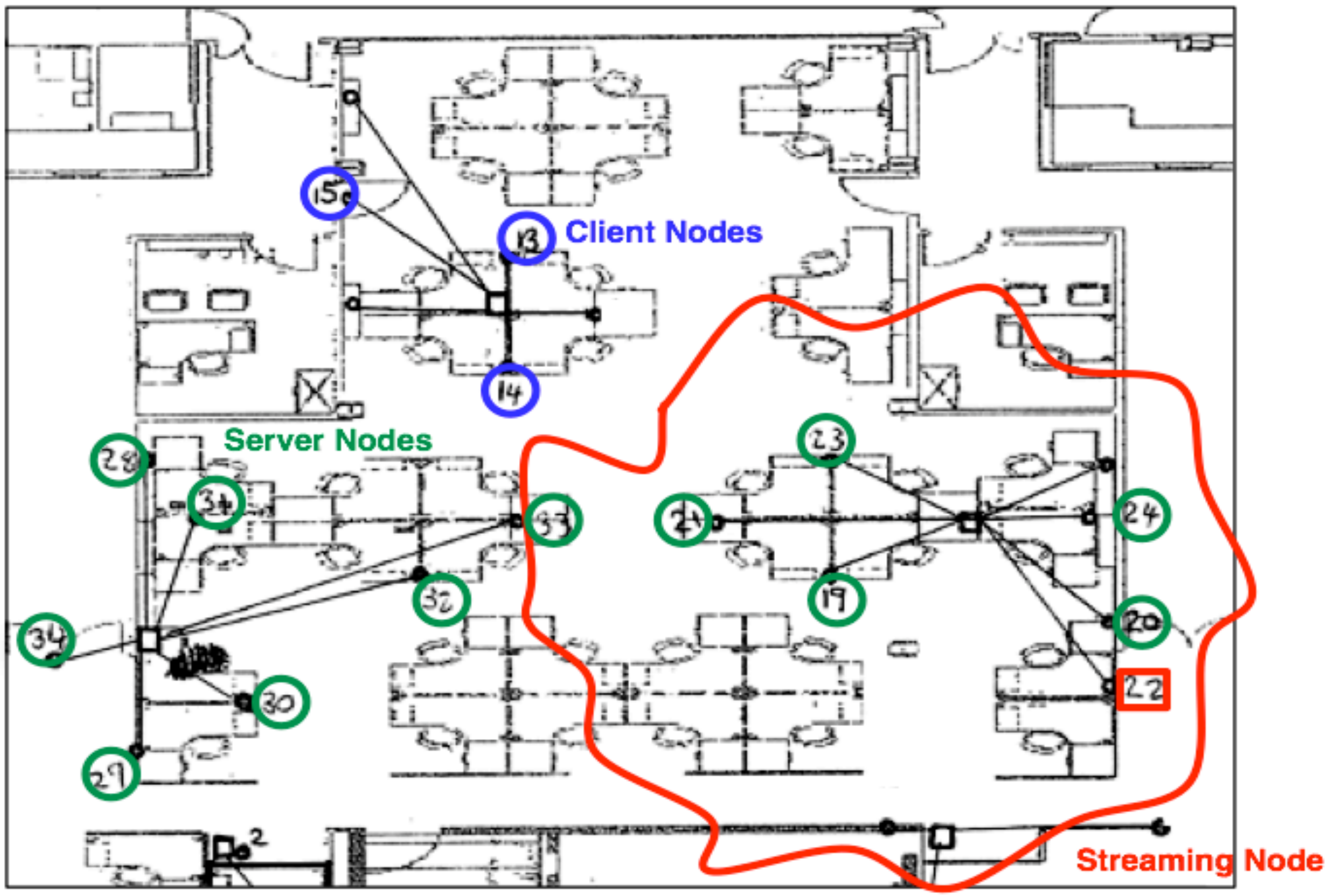


Experimental Results (2)

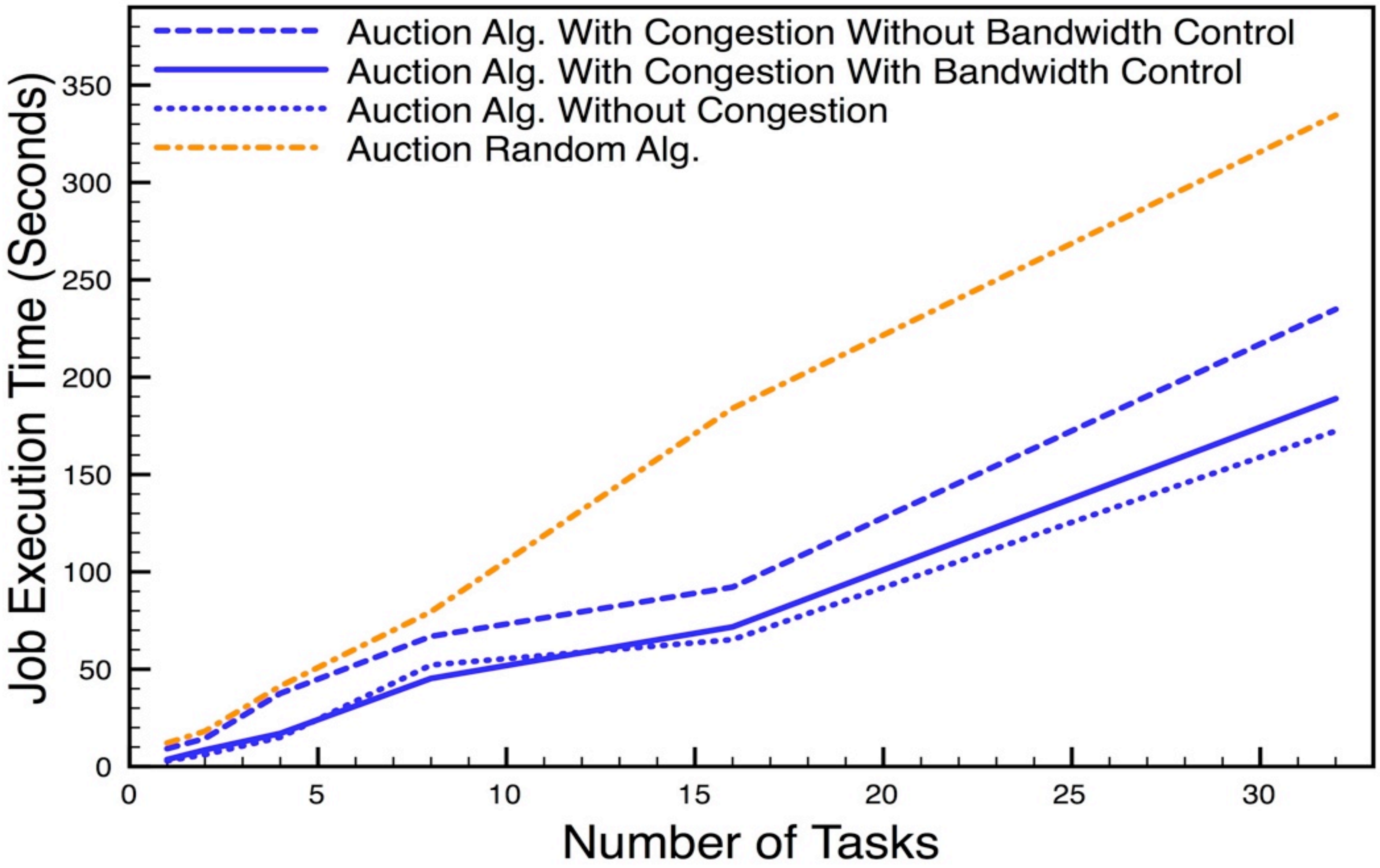


Large-Scale Testbed - II

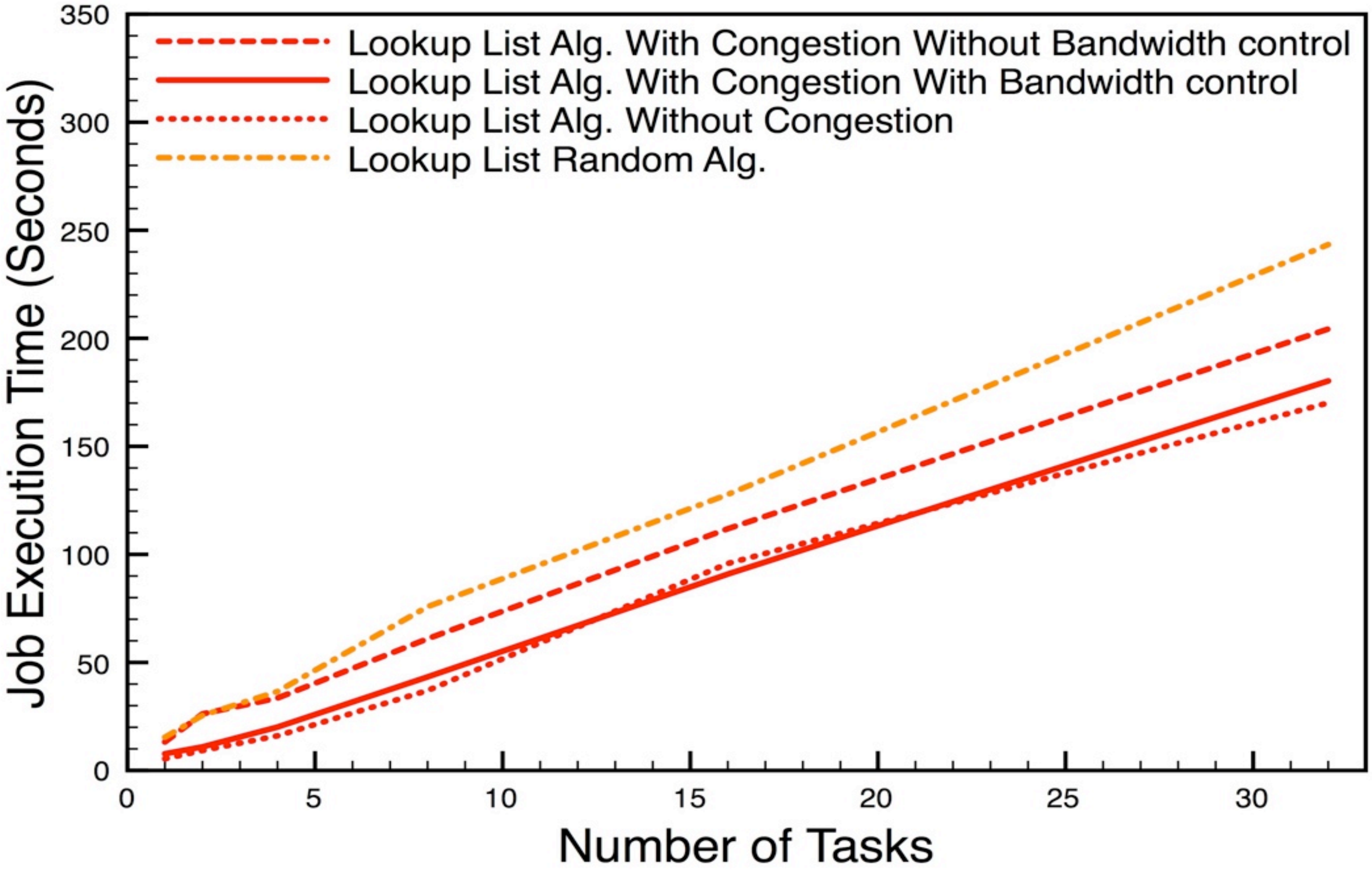
- HEN Mote Testbed (UCL)
- Radio Channel 26
- 32 Tasks Execution
- 50 Offload/Upload Packets
- UDP/TCP Communication



Experimental Results



Experimental Results (2)



Conclusion

In all different scenarios, although the overall performance was greatly affected by the changing environmental conditions, significant performance improvement (using latency as metric) was always obtained by taking the bandwidth into account during the collaborative distribution process.

Future Work

- Case study on a real-world application (e.g., localisation)
- Introduction of node mobility
- Introduction of node heterogeneity
- Introduction of security issues

Questions?