6.808 Mobile and Sensor Computing

aka IoT Systems

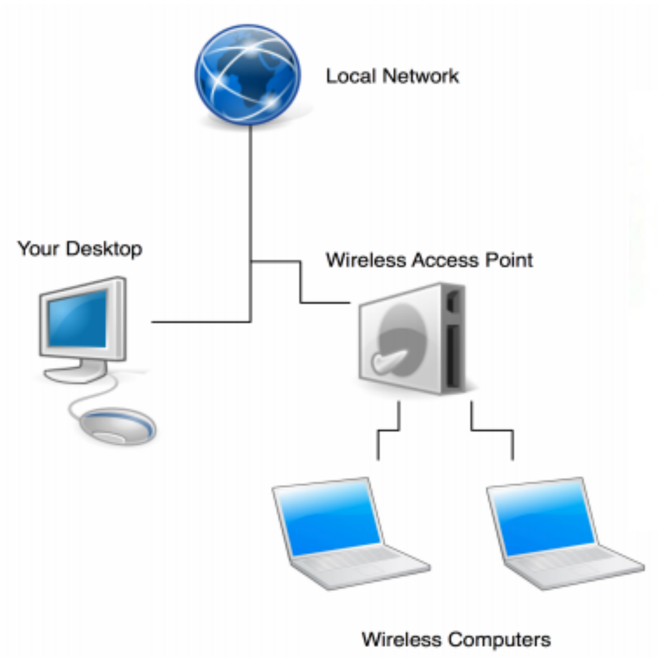
Lecture #5 (part 2)

Multi-Hop Routing

Wireless Network Architectures

There are 3 kinds of wireless network architectures

Access Network

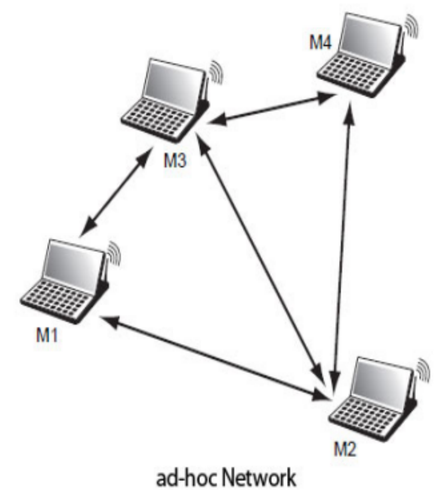


e.g., WiFi, cellular

Device-to-device

e.g., Bluetooth

Ad Hoc Network



e.g., leverage P2P to reach internet (crises)

One-hop

Multi-hop

Single Path Routing

Represent the wireless network as a graph

- Two nodes have an edge if they can communicate (i.e., are within radio range)
- Each edge is labeled with a weight (where a smaller weight indicates a preferred edge)

Run shortest path algorithm on the graph (e.g., Dijkstra)

- Produce the minimum weight path between every pair of nodes

How do you pick the edge weights?

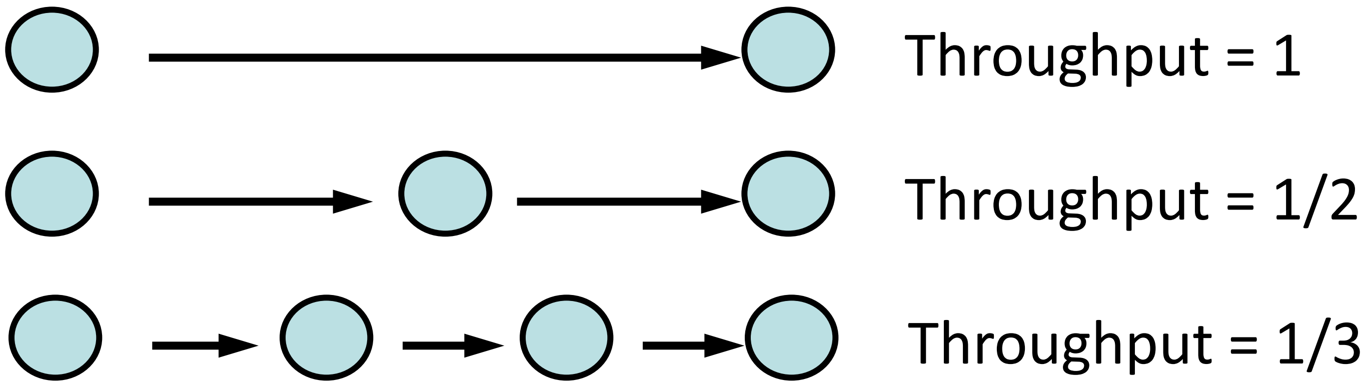
- i.e., what metric should shortest path minimize?

Focus of this lecture

Approach 1:
Assign all edges the same weight → Minimize number of hops

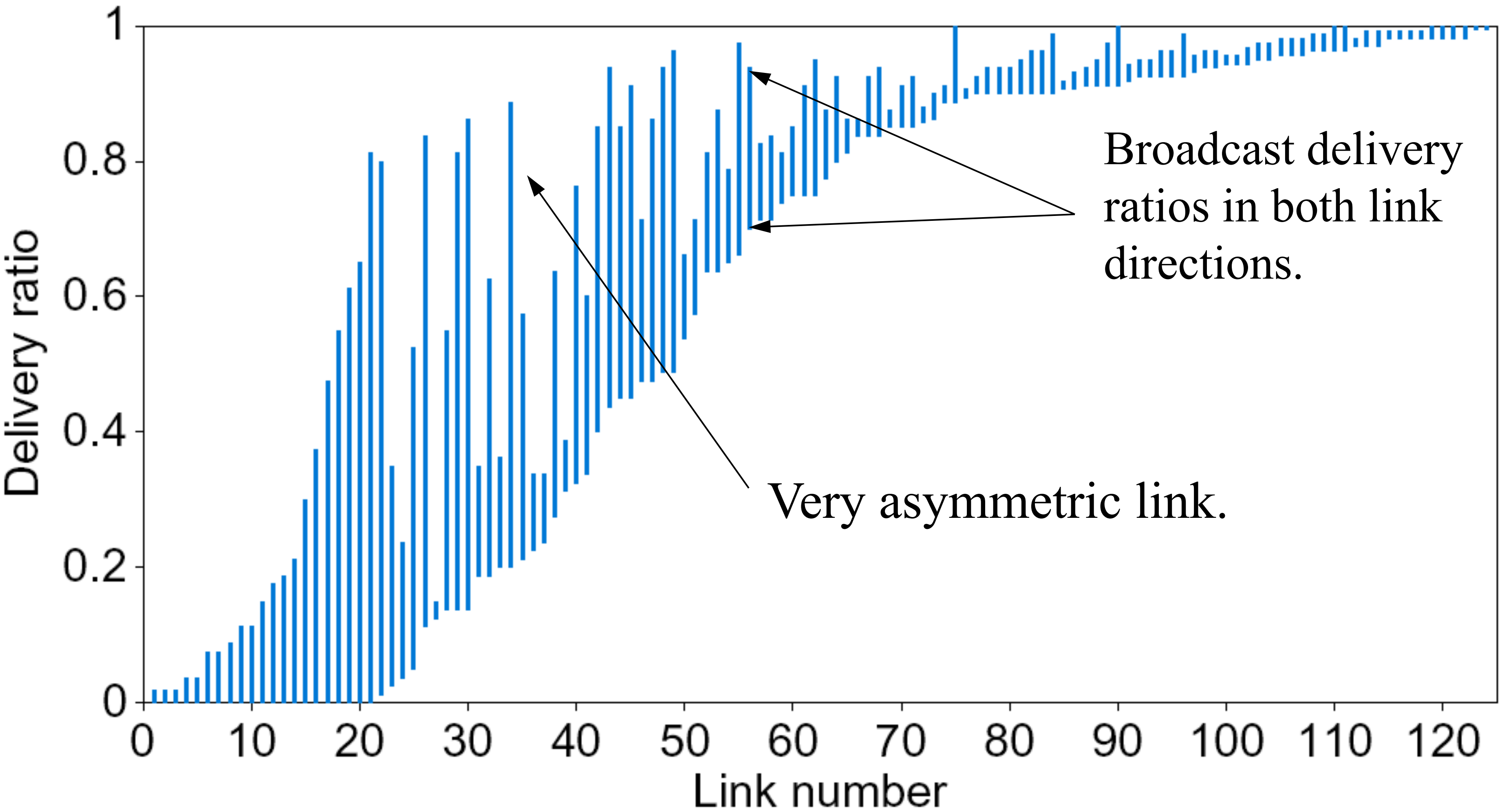
Reasoning:

- Links in route share radio spectrum
- Extra hops reduce throughput



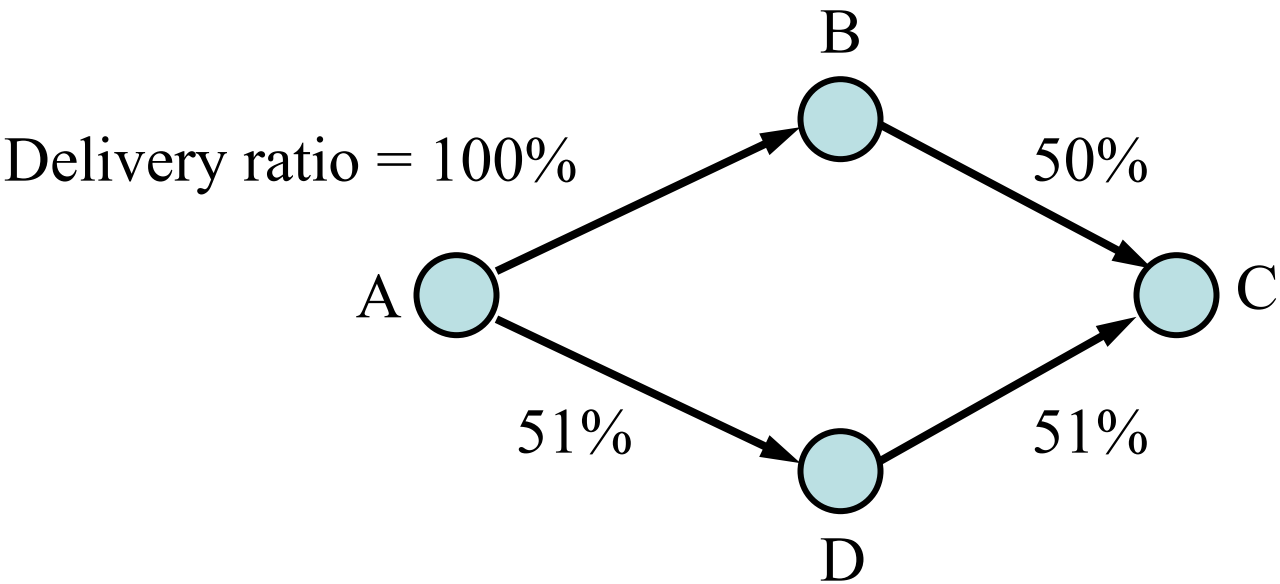
Pros? Cons?

Challenge: links are lossy and asymmetric



Different links have different loss rates
Further, the loss rate may be different in each direction

Approach 2:
Maximize bottleneck throughput

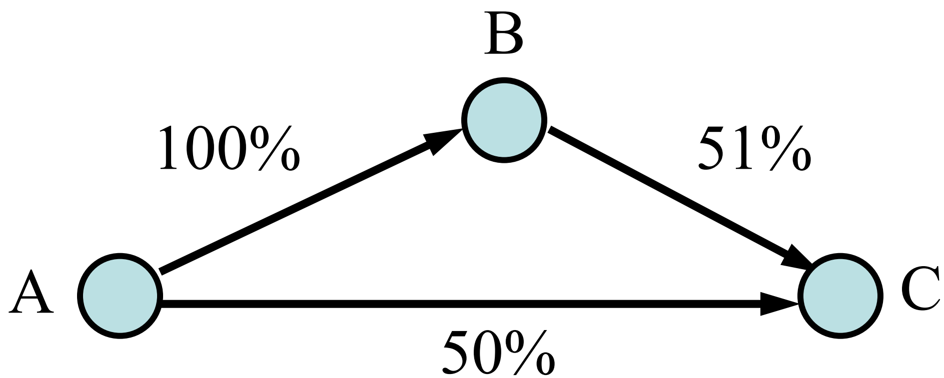


Bottleneck throughput: $\begin{cases} \text{A-B-C} = 50\% \\ \text{A-D-C} = \underline{51\%} \end{cases}$

Actual throughput: $\begin{cases} \text{A-B-C : ABBABBABB} = \underline{33\%} \\ \text{A-D-C : AADDAADD} = 25\% \end{cases}$

Pros? Cons?

Approach #3:
Maximize end-to-end delivery ratio



End-to-end delivery ratio:

- A-B-C = <u>51%</u>
- A-C = 50%

Actual throughput:

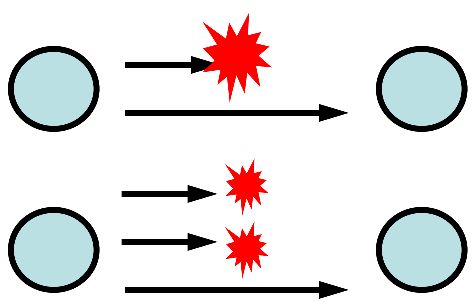
- A-B-C : ABBABBABB = 33%
- A-C : AAAAAAAAA = <u>50%</u>

Pros? Cons?

Approach #4: Wireless routing metric: ETX

Minimize total transmissions per packet
(ETX, ‘Expected Transmission Count’)

Link throughput ≈ 1/ Link ETX



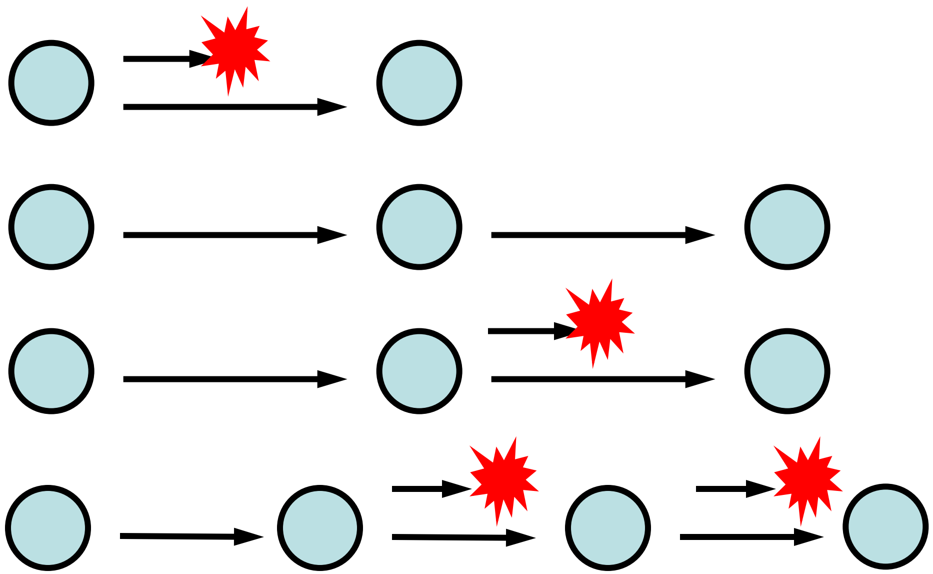
Delivery Ratio	Link ETX	Throughput
100%	1	100%
50%	2	50%
33%	3	33%

Calculating Link ETX

- Assuming 802.11 link-layer acknowledgments (ACKs) and retransmissions:
- P(TX success) = P(Data success) × P(ACK success)
- Link ETX = 1 / P(TX success)
  = 1 / [P(Data success) × P(ACK success)]
- Estimating link ETX:
- P(Data success) ≈ measured fwd delivery ratio r_{fwd}
- P(ACK success) ≈ measured rev delivery ratio r_{rev}
- Link ETX ≈ $1 / (r_{\text{fwd}} \times r_{\text{rev}})$

Route ETX

Route ETX = Sum of link ETXs



Route ETX	Throughput
1	100%
2	50%
2	50%
3	33%
5	20%

ETX Pros?

- ETX predicts throughput for short routes (1, 2, and 3 hops)

- ETX captures loss

- ETX captures asymmetry

ETX Caveats

- It is really hard to measure link quality/loss
  - Changes as a function of load
  - Changes with time

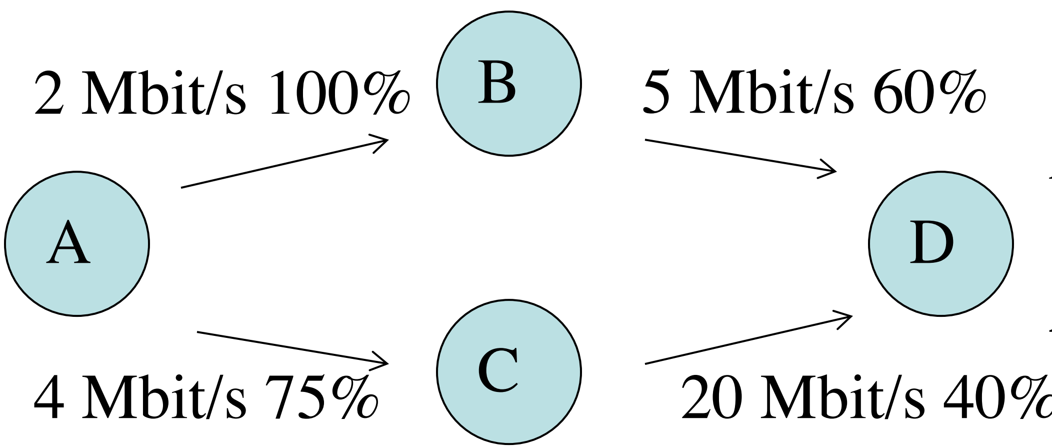
- ETX ignores differences in bit-rate and packet size

  ETT = ETX *(pkt_size/link-bit-rate)

- ETX ignores spatial re-use (i.e., assumes all links interfere)

From ETX to Expected Transmission Time (ETT)

- Extending to wireless networks with multiple bit rates
- Take into account both the delivery rate and the **time** taken to transmit packet (i.e., time occupied on "air" by packet)
- Assume pkt size = 20



ABD: 10*1+ 4*5/3 = 50/3

ACD: 5*4/3 + 1*5/2 = 55/6

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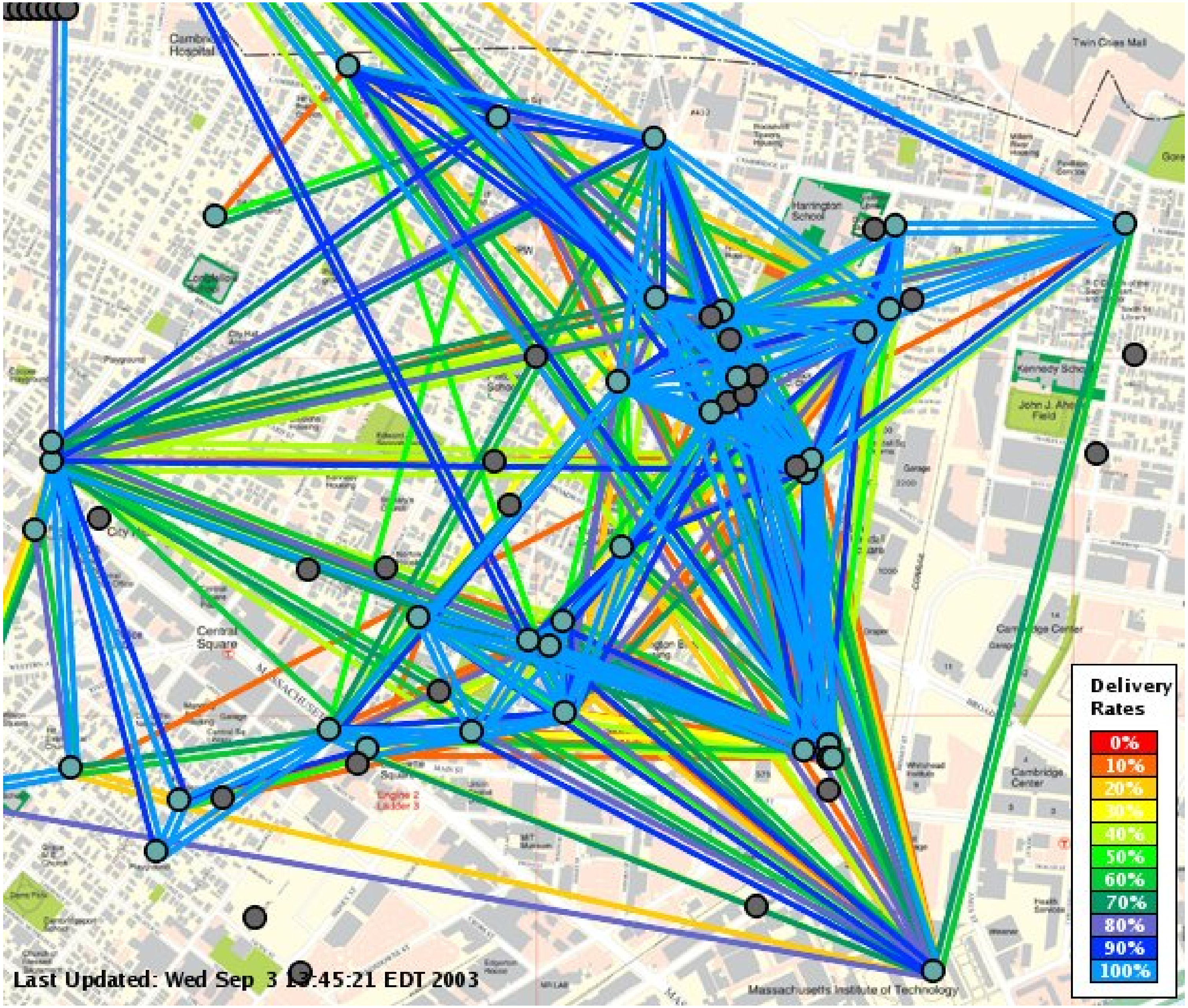

Delivery Rates
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
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