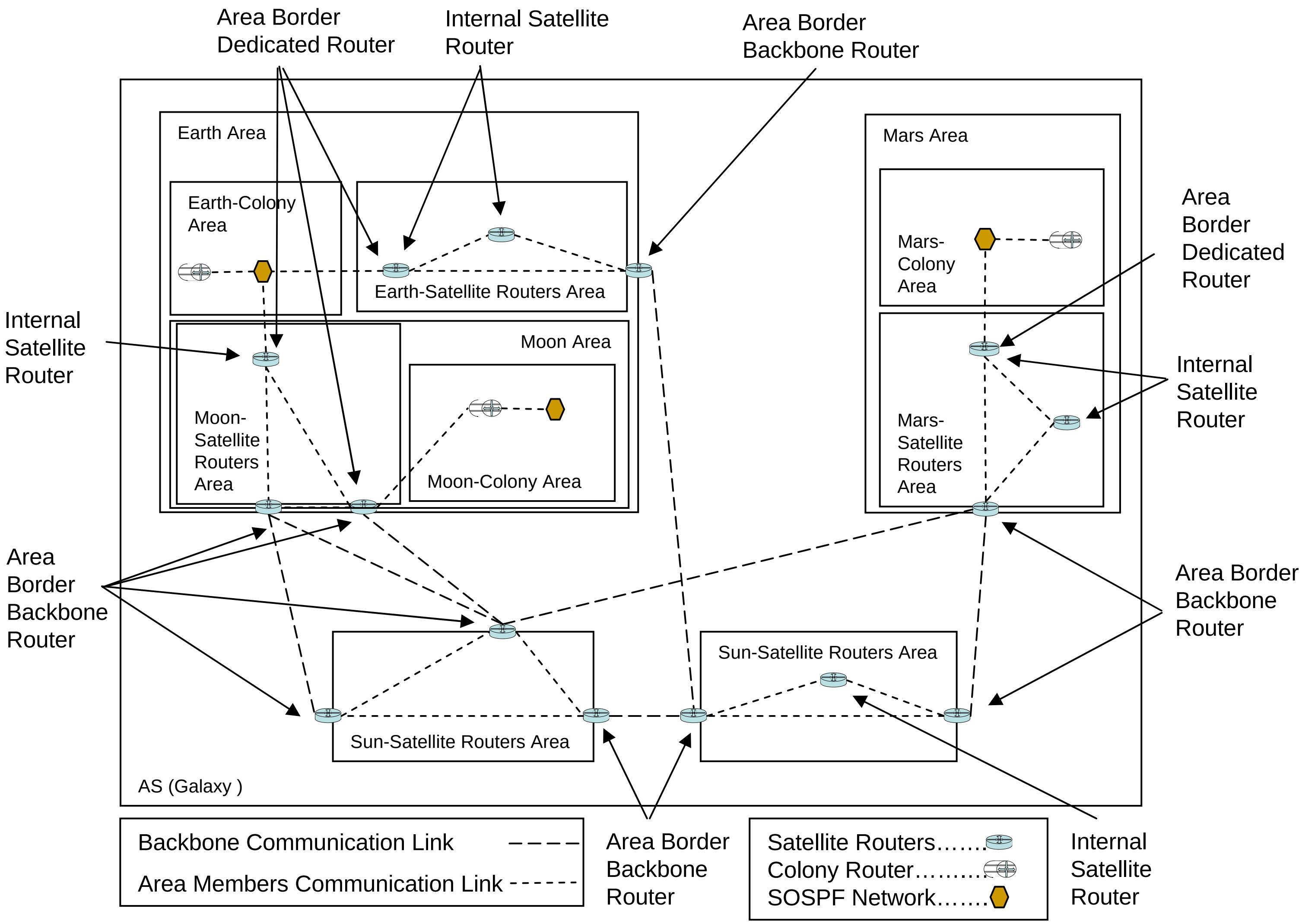
Space OSPF- Shortest Delay Intermittent Pathway Routing With Mobile Routers

Nouman Bantan
Kent State University
September 13, 2006

Space Routing

- An aspect of routing in space is the mobility of routers.
- Satellite routers are constantly moving which causes intermittent connectivity between one satellite routers to another satellite router.
- Space OSPF (SOSPF) provides routers on board satellite with the ability to compute near optimum routing table.

SOSPF Protocol Review

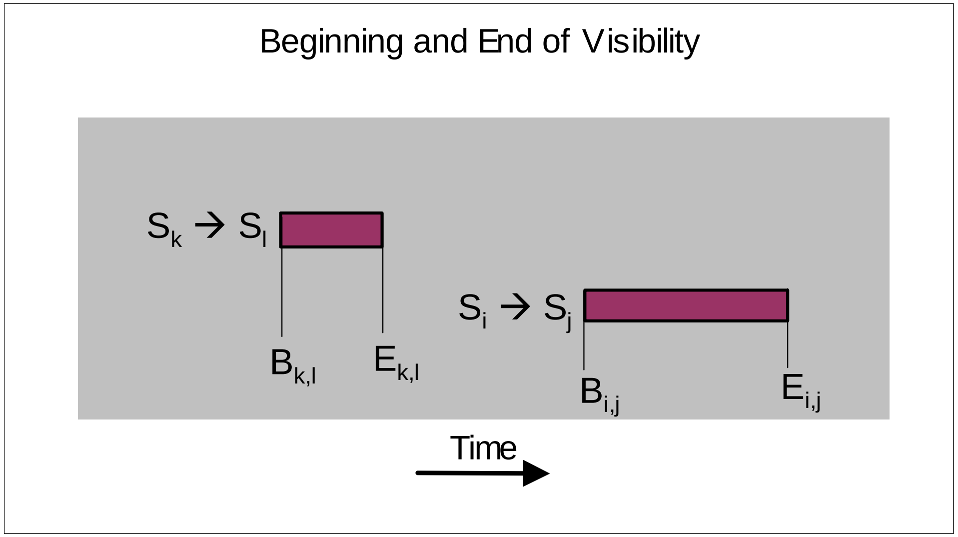


Space Router-LSA (SR-LSA) Example

Source Satellite Address		5F00:0000:C001:0400::/56
Destination Satellite Address		5F00:0000:c001:2C00::/56
Number of entries		3
Entry # 1	Begin time	2006:08:28:20:14:50
	End time	2006:08:29:20:14:50
	Propagation Delay	15
Entry # 2	Begin time	2006:08:29:40:30:05
	End time	2006:08:30:20:14:50
	Propagation Delay	20
Entry # 3	Begin time	2006:08:30:23:14:50
	End time	2006:08:31:20:14:50
	Propagation Delay	20

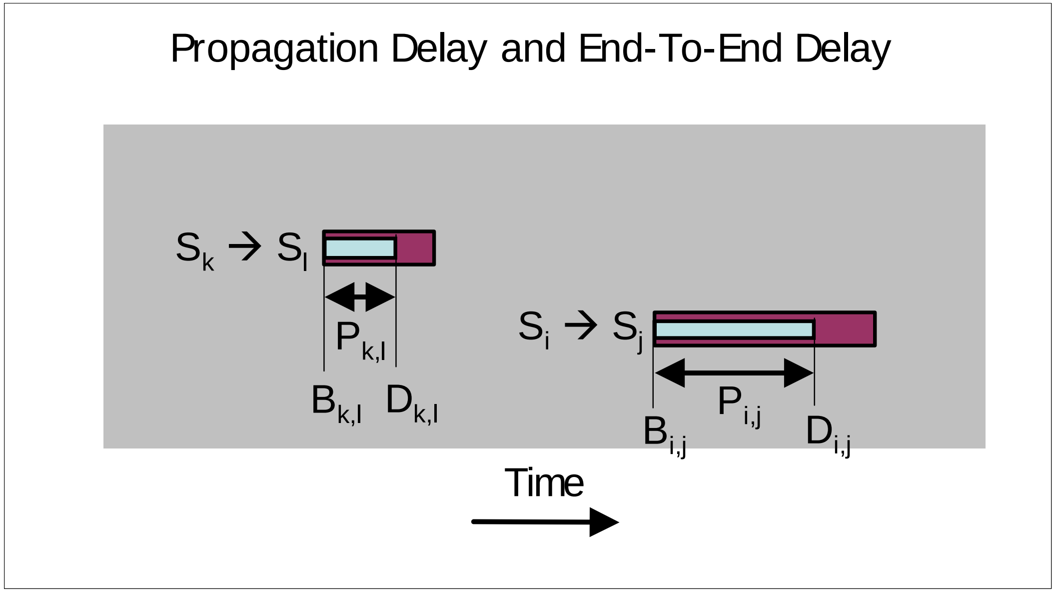
Shortest Delay Intermittent Pathway (SDIP) Routing Algorithm

- Using SR-LSAs:
  - Let n be the number of satellite routers in space
  - Let S_i be a satellite router where $0 \leq i \leq n$
  - Let $B_{i,j}$ is the beginning of the time slice where Satellite S_i is visible to satellite S_j
  - Let $E_{i,j}$ is the end of the time slice where satellite S_i is visible to satellite S_j.



Propagation Delay & End-to-End Delay

- Let $P_{i,j}$ is the propagation delay between satellites S_i to satellite S_j.
- Let $D_{i,j}$ be the end to end delay for a single transmission between satellite S_i and satellite S_j



SDIP: Initialize

- The first part of the SDIP routing algorithm is initializing the shortest path between every pair of satellite routers to the end to end delay using the direct link between them. i.e.,
  - $D_{i,j} = B_{i,j} + P_{i,j}$ where $0 \le i,j \le n$

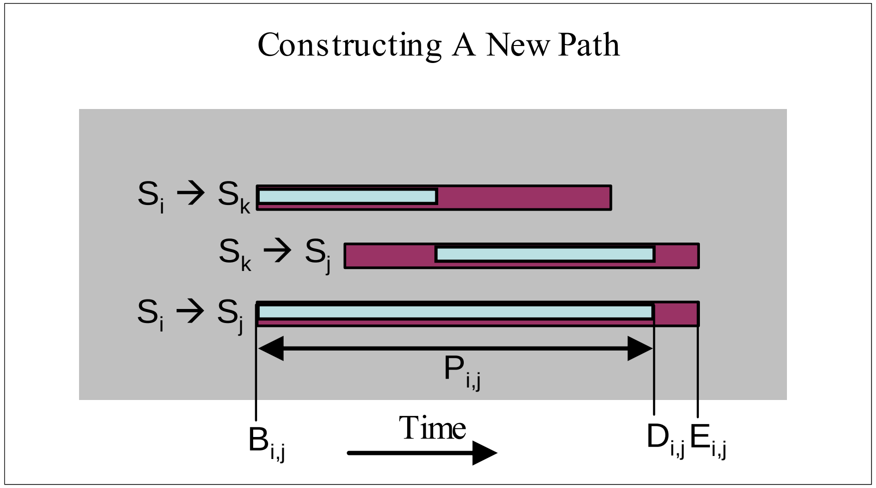
End-to-End Delay via a Third Satellite Router

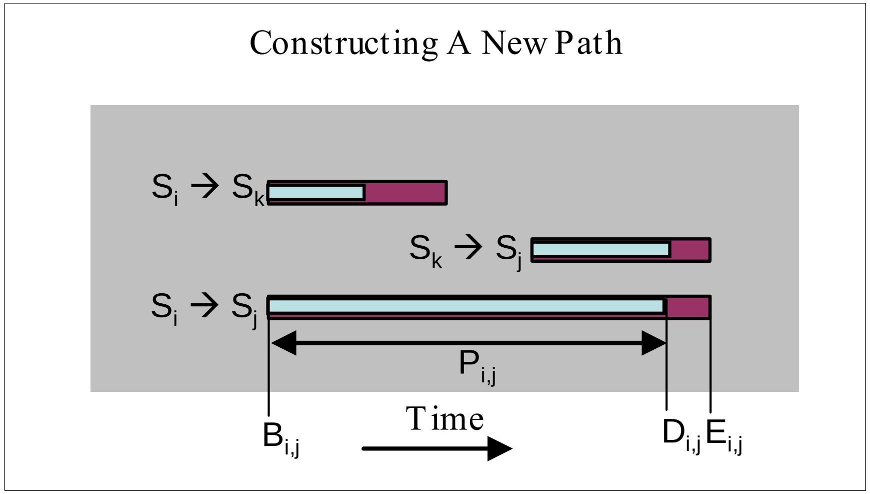
- For ease of terminology use, we will define a new parameter which represents the end-to-end delay path between one satellite router to another via a third satellite router, i.e.,
- Let $M_{i,k,j}$ be the end to end delay from satellite routers S_i to S_j via S_k

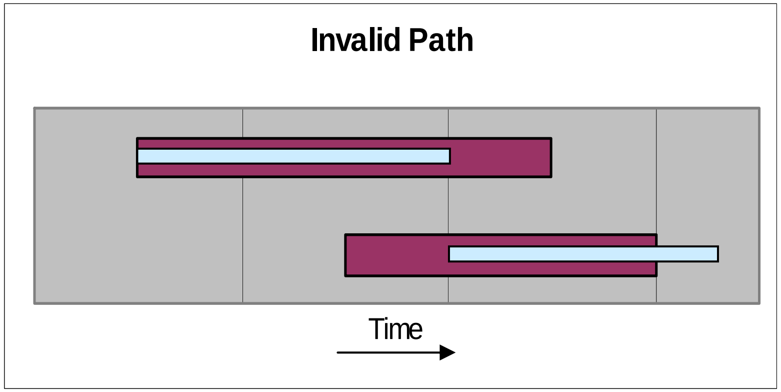
SDIP: Algorithm

- For each satellite router, call it S_k,
  - we check if the end-to-end delay between satellite router S_i and satellite router S_j via satellite router S_k is a small then the current end-to-end delay between satellite router S_i and satellite router S_j.
  - If the path via satellite router S_k is <u>valid</u> and has a smaller end-to-end delay than the current path, the path from satellite router S_i to satellite router S_k to satellite router S_j is the newly calculated shortest path between the satellite routers S_i and S_j

SDIP: New Path







SDIP: Example

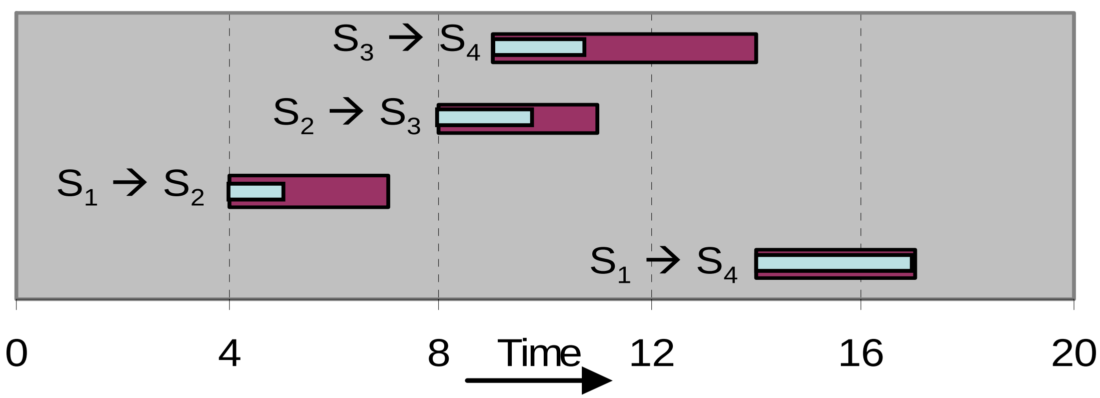
Beginning and end of visibility time slice

	S_1	S_2	S_3	S_4
S_1		4-7	∞	14-17
S_2	4-7		8-11	∞
S_3	∞	8-11		9-14
S_4	14-17	∞	9-14	

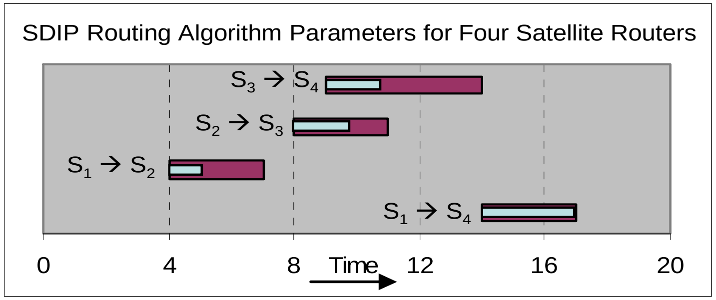
Propagation delay

	S_1	S_2	S_3	S_4
S_1		1	∞	3
S_2	∞		2	∞
S_3	∞	∞		2
S_4	∞	∞	∞	

SDIP Routing Algorithm Parameters for Four Satellite Routers

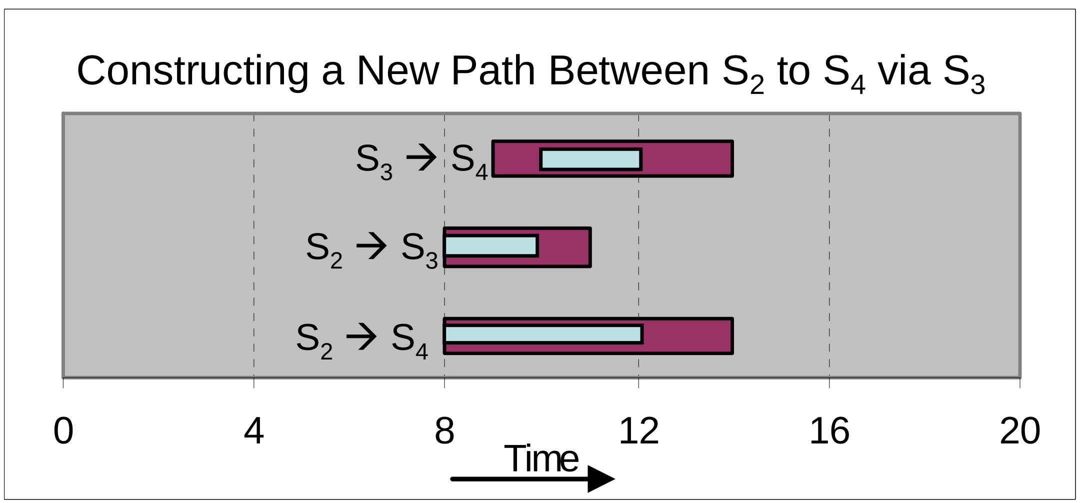


SDIP: First Run



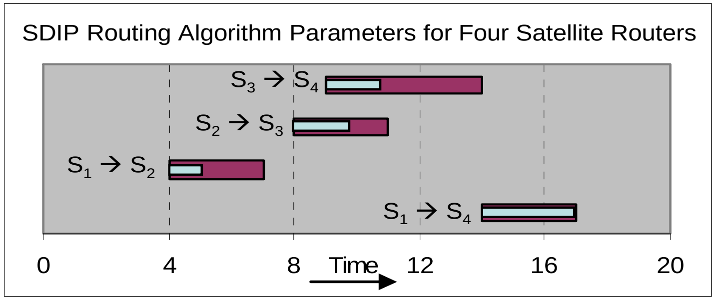
End-to-End delay E_{ij}

	S_1	S_2	S_3	S_4
S_1		5	∞	17
S_2	∞		10	∞
S_3	∞	∞		11
S_4	∞	∞	∞	



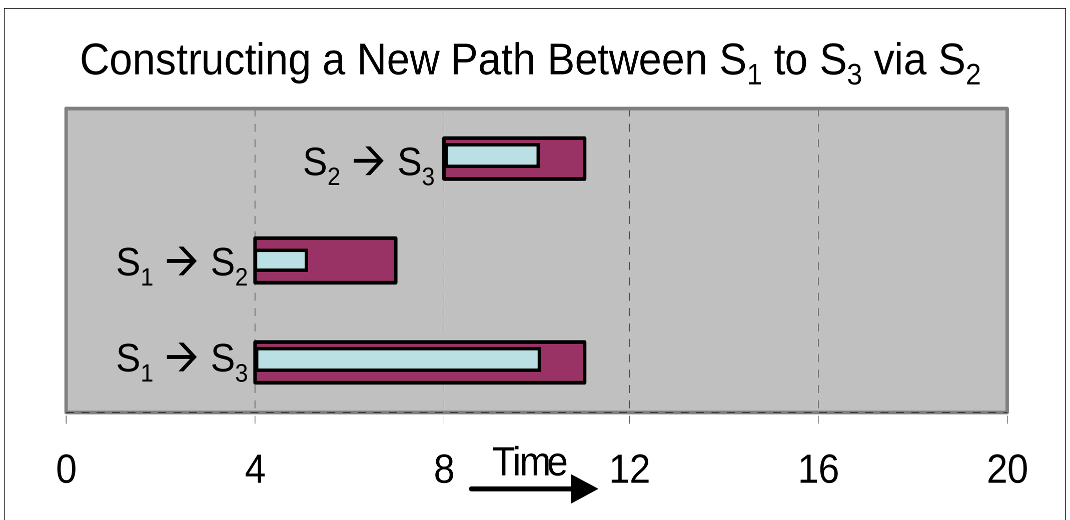
Parameter	Value
$B_{2,4} = B_{2,3}$	8
$E_{2,4} = E_{3,4}$	14
$D_{2,4} = D_{2,3} + P_{3,4}$	12
$P_{2,4} = D_{2,4} - B_{2,4}$	4

SDIP: Second Run



End-to-End delay E_{ij}

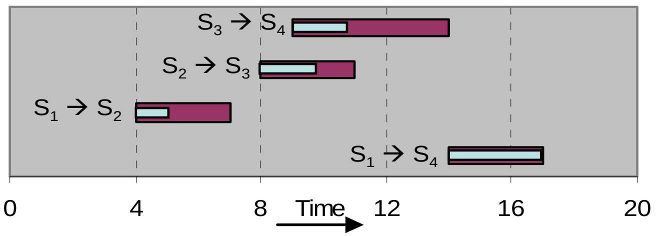
	S_1	S_2	S_3	S_4
S_1		5	∞	17
S_2	∞		10	12
S_3	∞	∞		11
S_4	∞	∞	∞	



Parameter	Value
$B_{1,3} = B_{1,2}$	4
$E_{1,3} = E_{2,3}$	11
$D_{1,3} = B_{2,3} + P_{2,3}$	10
$P_{1,3} = D_{1,3} - B_{1,3}$	6

SDIP: Third Run

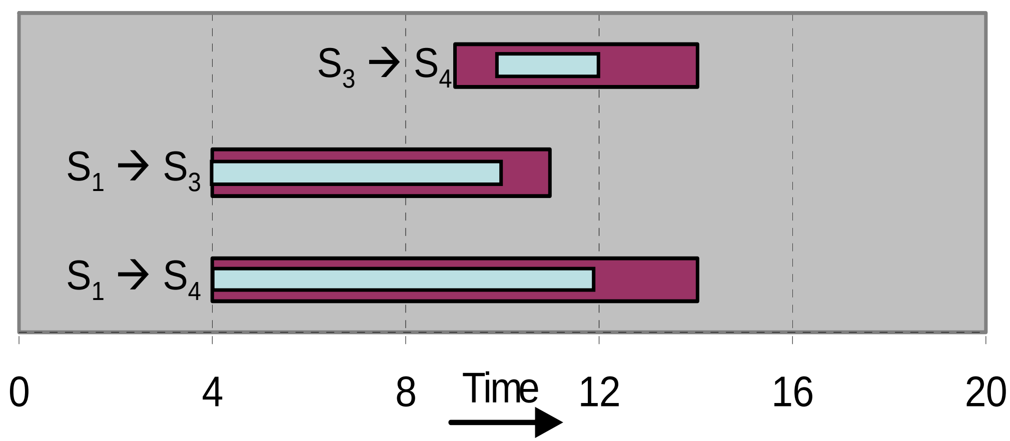
SDIP Routing Algorithm Parameters for Four Satellite Routers



End-to-End delay E_{ij}

	S_1	S_2	S_3	S_4
S_1		5	10	17
S_2	∞		10	12
S_3	∞	∞		11
S_4	∞	∞	∞	

Constructing a New Path Between S_1 to S_4 via S_3



Parameter	Valu e
$B_{1,4} = B_{1,3}$	4
$E_{1,4} = E_{3,4}$	14
$D_{1,4} = D_{1,3} + P_{3,4}$	12
$P_{1,4} = D_{1,4} - B_{1,4}$	8

SDIP: Example Results

End-to-End delay E_{ij}

	S_1	S_2	S_3	S_4
S_1		5	10	14
S_2	∞		10	12
S_3	∞	∞		11
S_4	∞	∞	∞	

Simulation Properties

- The routers are deployed on-board satellites placed on various mars and earth orbits.
- Our simulation makes use of real satellites' parameter proposed or currently used by NASA.
- In our space simulation, we set up various number of satellites in one orbits around Earth and Mars.
- We set the time and date of the simulation for one hour from 2002, August 1, 0:0:0 to 2002, August 11, 1:0:0.
- there are 1000 packets to be transferred from one satellite orbiting Earth to a satellite orbiting Mars. The packets sizes are from 112KB to 128KB.
- All satellites have a bandwidth of 128Kbps.
- We ran the simulation with seven scenarios.

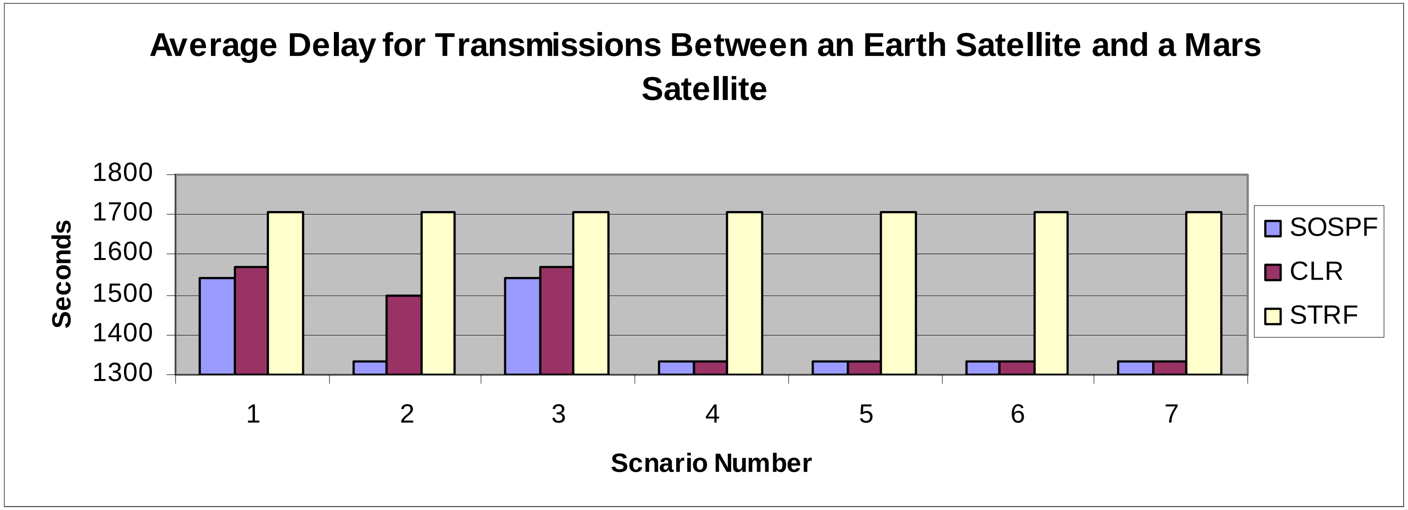
Simulation Scenarios

Scenario #	Mars Satellites		Earth Satellites
	Orbit 1	Orbit 2	Orbit1
1	1	0	3
2	1	1	3
3	1	0	6
4	1	1	6
5	3	0	3
6	3	3	3
7	3	3	6

Simulation Comparison

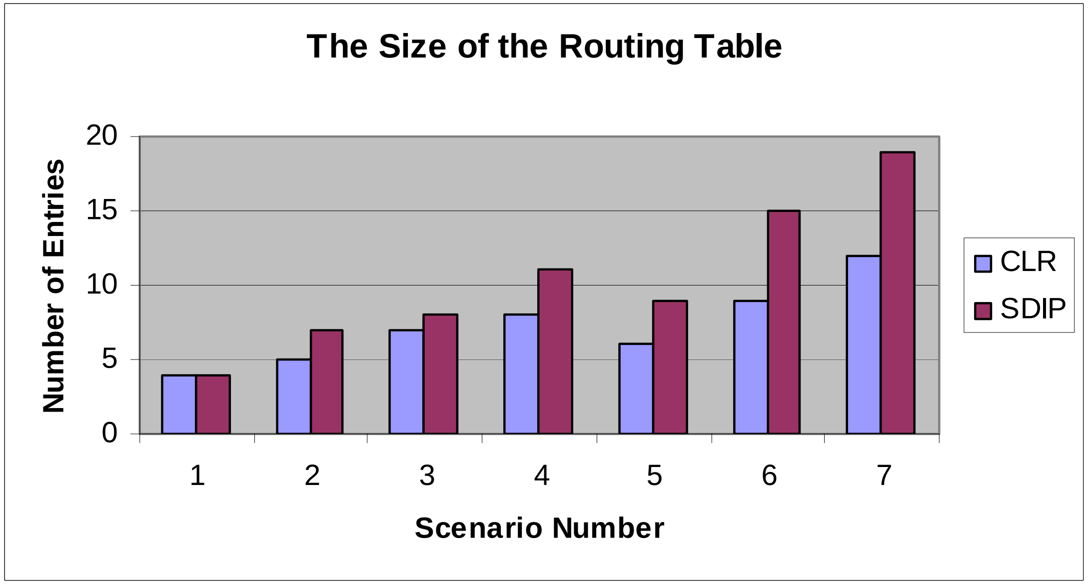
- Concurrent Link Routing (CLR) by Gnawali et al.
  - CLR is a shortest path algorithm with no intermittent connections
- Space-time routing framework (STRF) by Merugu et al.
  - Create a space-time routing tables
  - Next hop node is selected from the current hop
  - Destination and the arrival time of message, determine the next hop node

Simulation Results: End-to-End Delay



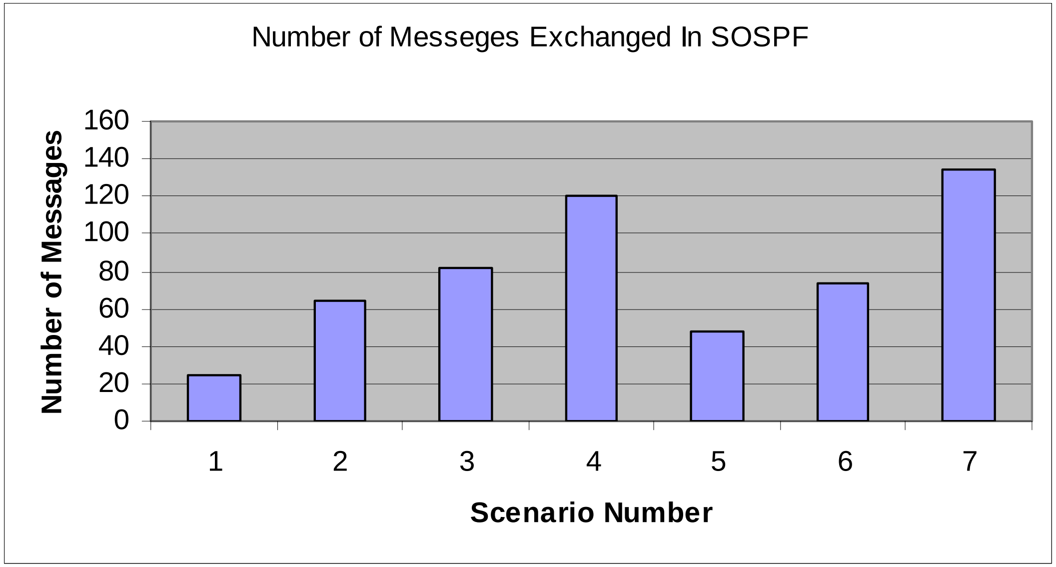
Scenario #	Mars Satellites		Earth Satellites
	Orbit 1	Orbit 2	Orbit1
1	1	0	3
2	1	1	3
3	1	0	6
4	1	1	6
5	3	0	3
6	3	3	3
7	3	3	6

Simulation Results: Routing Table Size



Scenario #	Mars Satellites		Earth Satellites
	Orbit 1	Orbit 2	Orbit1
1	1	0	3
2	1	1	3
3	1	0	6
4	1	1	6
5	3	0	3
6	3	3	3
7	3	3	6

Simulation Results: Number of Messages



Scenario #	Mars Satellites		Earth Satellites
	Orbit 1	Orbit 2	Orbit1
1	1	0	3
2	1	1	3
3	1	0	6
4	1	1	6
5	3	0	3
6	3	3	3
7	3	3	6

Conclusion

- With the Shortest Satellite Delay routing algorithm, each satellite router has the ability to calculate shortest path to any other satellite router now and in the future.
- Using Space OSPF (SOSPF), many variables can be added to the SDIP routing algorithm to improve its outcomes, e.g., satellite power limitation or transmission success probability.