# Computer Networks CS3205 Assignment 3

# OSPF Routing Algorithm

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#### 1 Objective

The objective of this assignment is to emulate a simplified version of the Open Shortest Path First (OSPF) routing protocol, as explained in the problem statement and observe the results.

#### 2 Introduction

Open Shortest Path First (OSPF) is a routing protocol for Internet Protocol (IP) networks. It uses Link State Routing (LSR) algorithm. The shortest path is calculated based on the cost of the route, making it adaptive to the changing network conditions.

All routers keep sending hello packets, and thus changes in the cost of their links become known to neighboring routers. The information about the cost of a link, is then cascaded through the network because OSPF routers advertise the information they receive from one neighboring router to all other neighboring routers. This process of flooding link state information through the network is known as synchronization Based on this information, all routers continuously update their link state databases with information about the network topology and adjust their routing tables.

The algorithm that is emulated in the assignment follows these principles.

#### 3 Experimental details

The algorithm in this experiment has 3 adjustable parameters.

- $\bullet$  hi Hello interval
- lsai LSA interval
- spfi SPF interval

They denote the periods at which HELLO packets, LSA packets, SPF calculation repeat during execution.

#### 3.1 Experimental/Simulation setup

These three parameters can be passed to the ospf executable along with the node id, the name of the infile and outfile to generate the outfiles. The infile consists of the information about the network such as number of routers, links and details about links and the range of costs for each link. The outfile consists of routing tables which are printed every spfi seconds.

For the emulation of the network, a program instance should be running for every router to be emulated. That is automated using the bash script routersetup.sh to run multiple instances in parallel. The number of routers should be passed as a command-line argument to the script.

#### 3.2 Entities involved and functions in each entity

ospf.cpp has the code for the emulation of the algorithm. It takes in parameters through command line and writes the routing table of the given router to an outfile of the specified name.

Sending HELLO, LSA packets and calculating paths should be done periodically and should not interrupt the receiving packets. Therefore, those tasks are run concurrently by spawning a thread for each task. This is done by the function threadStart().

```
void threadStart(function<void()> func, unsigned int interval)
{
    thread([func, interval]() {
        while (true)
        {
            auto x = chrono::steady_clock::now() +
            chrono::milliseconds(interval);
            func();
            this_thread::sleep_until(x);
        }
    }).detach();
}
```

This creates a new thread that executes the given function every interval ms. Using this, we create new threads for 3 functions - sendHello, sendLSA, calculatePaths.

routersetup.sh is a bash script that takes the number of routers as a command-line argument and runs multiple instances of the executable in parallel. All the processes can be killed by using Ctrl + C.

#### 4 Results and Observations

#### 4.1 Example 1

The infile consists of the following

```
8 20

1 0 5 20

1 2 12 30

2 0 13 17

3 1 11 16

3 2 7 19

0 3 2 10

4 5 16 25

4 6 27 31

4 7 21 24

5 6 31 35

5 7 10 15
```

```
6 7 23 27
0 4 1 30
4 1 9 19
1 5 12 14
7 2 13 20
3 6 11 17
4 2 4 7
3 7 10 13
6 2 27 20
```

The routing tables are as the following

Routing Table Destination 1 2 3 4 5 6 7 Routing Table Destination 1 2 3 4 5 6 7	Path 01 02 03 04 015 036 037	Cost 11 16 5 14 24 19		Routing Table Destination 0 2 3 4 5 6 7 Routing Table Destination 0 2 3 4 5 6 7	Path 10 12 13 14 15 136 137	Cost 11 13 13 15 12 27 23	
	(a) Node	0			(b) Node	e 1	
Routing Table Destination 0 1 3 4 5 6 7 Routing Table Destination 0 1 3 4 5 6 7	Path 20 21 23 24 245 26 27	Cost 16 12 19 4 20 27 19 no. 2 Cost 17 15 14 5 21 29 19		Destination 0 1 2 4 5 6	Path 30 31 32 304 375 36 37	Cost 5 13 19 19 23 11 11 no. 3 Cost 10 14 14 19 25 17 12	

Figure 1: Routing tables for the first topology

2 3 5 6 7 Routing Table f Destination 0 1 2 3 5 6	47 for Node Path 40 41 42 423 45 46 47	21 no. 4 Cost 20 16 5 19 16 27 22	at	time 20	6 7 Routing Table Destination 0 1 2 3 4 6	56 57 for Node Path 510 51 542 573 54 56	33 14 no. 5 Cost 25 14 21 21 16 33 11	at	time	20
	(a) Node	4				(b) Node	e 5			
Routing Table for Destination  1 2 3 4 5 7 Routing Table for Destination 0 1 2 3 4 5 7	Path 630 631 62 63 64 65 637	Cost 16 24 27 11 30 33 22 no. 6 Cost 27 31 29 17 27 33 26			Routing Table Destination 0 1 2 3 4 5 6 Routing Table Destination 0 1 2 3 4 5 6	Path 730 731 72 73 74 75 736	Cost 16 24 19 11 21 14 22 no. 7 Cost 22 25 19 12 22 11 26			

Figure 2: Routing tables for the first topology (continued...)

#### Example 2 4.2

The infile consists of the following

- 8 22
- 0 1 4 10
- 1 2 3 9
- 2 0 6 10
- 3 1 4 10
- 3 2 3 9
- 0 3 6 10
- 0 4 2 5
- 4 1 7 20
- 2 4 3 7
- 4 3 9 17
- 0 5 10 15
- 5 1 13 20
- 2 5 20 27
- 5 3 25 26
- 0 6 12 16
- 6 1 13 17
- 2 6 4 6
- 6 3 1 5
- 0 7 9 15
- 7 1 15 20
- 2 7 19 24
- 7 3 30 35

#### The routing tables are as follows

a .: = .:		_			<b>a a</b>					
			at	time 10	Routing Table			at	time	10
Destination	Path	Cost			Destination	Path	Cost			
1	01	4			0	10	4			
2	02	9			2	12	3			
3	03	9			3 4 5 6	13	4			
4	04	3			4	104	7			
5	05	15			5	15	13			
6	036	14			6	126	8			
7	07	15			7	17	15			
Routing Table	for Node	no. 0	at	time 20	Routing Table	for Node	no. 1	at	time	20
Destination	Path	Cost			Destination	Path	Cost			
1	01	6			0	10	6			
2	042	8			2	12	3			
3	03	9			3	13	4			
4	04	5			4	124	6			
5	05	15			5	15	19			
6	036	11			5 6	136	6			
7	07	12			7	107	18			
*	••									
	(a) Mada	0				(1 ) NT 1	1			
	(a) Node	: 0				(b) Node	1			
Routing Table	` '		at	time 10	Routing Table	. ,		at	time	10
	` '		at	time 10	Routing Table Destination	. ,		at	time	10
Routing Table Destination 0	for Node	no. 2	at	time 10	Routing Table Destination 0	for Node	no. 3	at	time	10
Destination 0	for Node Path	no. 2 Cost 7	at	time 10	Destination 0	for Node Path	no. 3 Cost	at	time	10
Destination 0 1	for Node Path 210 21	no. 2 Cost 7 3	at	time 10	Destination 0 1	for Node Path 310	no. 3 Cost 8	at	time	10
Destination 0 1 3	for Node Path 210 21 213	no. 2 Cost 7 3 7	at	time 10	Destination 0 1 2	for Node Path 310 31	no. 3 Cost 8 4	at	time	10
Destination 0 1 3	for Node Path 210 21 213 24	no. 2 Cost 7 3 7 6	at	time 10	Destination 0 1 2 4	for Node Path 310 31 362 34	no. 3 Cost 8 4 7 9	at	time	10
Destination 0 1 3 4	for Node Path 210 21 213 24 215	no. 2 Cost 7 3 7 6 16	at	time 10	Destination 0 1 2 4 5	for Node Path 310 31 362 34 315	no. 3 Cost 8 4 7 9	at	time	10
Destination 0 1 3	for Node Path 210 21 213 24 215 26	no. 2 Cost 7 3 7 6 16 5	at	time 10	Destination 0 1 2 4 5	for Node Path 310 31 362 34 315 36	no. 3 Cost 8 4 7 9 17 2	at	time	10
Destination 0 1 3 4 5 6	for Node Path 210 21 213 24 215 26 217	no. 2 Cost 7 3 7 6 16 5			Destination 0 1 2 4 5 6	for Node Path 310 31 362 34 315 36 317	no. 3 Cost 8 4 7 9 17 2			
Destination 0 1 3 4 5 6 7 Routing Table	for Node Path 210 21 213 24 215 26 217 for Node	no. 2 Cost 7 3 7 6 16 5 18			Destination 0 1 2 4 5 6 7 Routing Table	for Node Path 310 31 362 34 315 36 317 for Node	no. 3 Cost 8 4 7 9 17 2 19			
Destination 0 1 3 4 5 6 7 Routing Table Destination	for Node Path 210 21 213 24 215 26 217 for Node Path	no. 2 Cost 7 3 7 6 16 5 18 no. 2 Cost			Destination 0 1 2 4 5 6 7 Routing Table Destination	for Node     Path     310     31     362     34     315     36     317 for Node     Path	no. 3 Cost 8 4 7 9 17 2 19 no. 3 Cost			
Destination  1 3 4 5 6 7 Routing Table Destination 0	for Node Path 210 21 213 24 215 26 217 for Node Path 20	no. 2 Cost 7 3 7 6 16 5 18 no. 2 Cost 9			Destination 0 1 2 4 5 6 7 Routing Table Destination 0	for Node Path 310 31 362 34 315 36 317 for Node Path 30	no. 3 Cost 8 4 7 9 17 2 19 no. 3 Cost 9			
Destination  1 3 4 5 6 7 Routing Table Destination 0 1	for Node Path 210 21 213 24 215 26 217 for Node Path 20 21	no. 2 Cost 7 3 7 6 16 5 18 no. 2 Cost 9			Destination 0 1 2 4 5 6 7 Routing Table Destination 0	for Node Path 310 31 362 34 315 36 317 for Node Path 30 31	no. 3 Cost 8 4 7 9 17 2 19 no. 3 Cost 9			
Destination 0 1 3 4 5 6 7 Routing Table Destination 0 1	for Node Path 210 21 213 24 215 26 217 for Node Path 20 21 23	no. 2 Cost 7 3 7 6 16 5 18 no. 2 Cost 9 3			Destination 0 1 2 4 5 6 7 Routing Table Destination 0 1	for Node Path 310 31 362 34 315 36 317 for Node Path 30 31 32	no. 3 Cost 8 4 7 9 17 2 19 no. 3 Cost 9 7 6			
Destination 0 1 3 4 5 6 7 Routing Table Destination 0 1	for Node Path 210 21 213 24 215 26 217 for Node Path 20 21 23 24	no. 2 Cost 7 3 7 6 16 5 18 no. 2 Cost 9 3 6 4			Destination 0 1 2 4 5 6 7 Routing Table Destination 0 1	for Node Path 310 31 362 34 315 36 317 for Node Path 30 31 32 324	no. 3 Cost 8 4 7 9 17 2 19 no. 3 Cost 9 7 6			
Destination 0 1 3 4 5 6 7 Routing Table Destination 0 1	for Node Path 210 21 213 24 215 26 217 for Node Path 20 21 23 24 215	no. 2 Cost 7 3 7 6 16 5 18 no. 2 Cost 9 3 6 4 22			Destination 0 1 2 4 5 6 7 Routing Table Destination 0 1 2 4 5	for Node Path 310 31 362 34 315 36 317 for Node Path 30 31 32 324 315	no. 3 Cost 8 4 7 9 17 2 19 no. 3 Cost 9 7 6 9 23			
Destination  1 3 4 5 6 7 Routing Table Destination 0 1 3 4 5	for Node Path 210 21 213 24 215 26 217 for Node Path 20 21 23 24 215 26	no. 2 Cost 7 3 7 6 16 5 18 no. 2 Cost 9 3 6 4 22 6			Destination 0 1 2 4 5 6 7 Routing Table Destination 0 1 2 4 5	for Node Path 310 31 362 34 315 36 317 for Node Path 30 31 32 324 315 36	no. 3 Cost 8 4 7 9 17 2 19 no. 3 Cost 9 7 6 9 23 5			
Destination 0 1 3 4 5 6 7 Routing Table Destination 0 1	for Node Path 210 21 213 24 215 26 217 for Node Path 20 21 23 24 215	no. 2 Cost 7 3 7 6 16 5 18 no. 2 Cost 9 3 6 4 22			Destination 0 1 2 4 5 6 7 Routing Table Destination 0 1 2 4 5	for Node Path 310 31 362 34 315 36 317 for Node Path 30 31 32 324 315	no. 3 Cost 8 4 7 9 17 2 19 no. 3 Cost 9 7 6 9 23			

 $\begin{array}{c} \text{(c) Node 2} \end{array} \hspace{2cm} \text{(d) Node 3}$ 

Figure 3: Routing tables for the second topology

Routing Table	for Node	no. 4	at	time	10	<mark>R</mark> outing Destinat	Table	for	Node th	no. 5 Cost	at	time	10
Destination	Path	Cost				0 0	LUII	50		15			
0 1	40	3				1		51		13			
	401	7				2		51		16			
2	42	6				3		51		17			
3	4013	11				4		50		18			
5 6	405 426	18 11				6			.36	20			
0	426 407	18				7		51		28			
/ Routing Table			-+	timo	20	, Routing	Table				at	time	20
Destination	Path	Cost	aι	t tille	20	Destinat	tion	Da	th	Cost	at	c cinc	20
	40	5				0	COII	50		15			
0 1	40 421	10				1		51		19			
	421	4				2		51		22			
2	423	7				3		51		23			
5	423	20				4		50		20			
6	405	8				6			.36	25			
7	426	o 17				7		50		27			
7	407	17				′		50	'	21			
	(a) Node	4						(b)	Node	5			
Routing Table	for Node	no. 6	at	time						no. 7	at	time	10
Destination	Path	Cost	at	time	ı	Destinat		Pa	th	Cost	at	time	10
Destination 0	Path 6310	Cost 11	at	time		Destinat 0		Pa 70	th	Cost 15	at	time	10
Destination 0 1	Path 6310 631	Cost	at	time		Destinat 0 1		Pa 70 71	th	Cost 15 15	at	time	10
Destination 0 1 2	Path 6310 631 62	Cost 11 7 6	at	time		Destinat 0 1		Pa 70 71 71	th .2	Cost 15 15 18	at	time	10
Destination 0 1 2	Path 6310 631 62 63	Cost 11 7 6 3	at	time		Destinat 0 1 2 3		Pa 70 71 71 71	th .2 .3	Cost 15 15 18 19	at	time	10
Destination 0 1 2	Path 6310 631 62 63 624	Cost 11 7 6 3 12	at	time		Destinat 0 1 2 3		Pa 70 71 71 71 70	th 2 3	Cost 15 15 18 19 18	at	time	10
Destination 0 1 2	Path 6310 631 62 63 624 6315	Cost 11 7 6 3 12 20	at	time		Destinat 0 1 2 3		Pa 70 71 71 71 70	2 3 4	Cost 15 15 18 19 18 30	at	time	10
Destination 0 1 2 3 4 5	Path 6310 631 62 63 624 6315 6317	Cost 11 7 6 3 12 20 22				Destinat 0 1 2 3 4 5	tion	Pa 70 71 71 70 70 71	th 2 3 4 5 36	Cost 15 15 18 19 18 30 22			
Destination  1 2 3 4 5 7 Routing Table	Path 6310 631 62 63 624 6315 6317 for Node	Cost 11 7 6 3 12 20 22 no. 6			20	Destinat 0 1 2 3 4 5 6 Routing	tion Table	Pa 70 71 71 70 70 71 for	th 2 3 4 5 36 Node	Cost 15 15 18 19 18 30 22 no. 7			
Destination  1 2 3 4 5 7 Routing Table	Path 6310 631 62 63 624 6315 6317 for Node Path	Cost 11 7 6 3 12 20 22 no. 6 Cost			20	Destinat 0 1 2 3 4 5 6 Routing Destinat	tion Table	Pa 70 71 71 70 70 71 for	th 2 3 4 5 36 Node	Cost 15 15 18 19 18 30 22 no. 7 Cost			
Destination  1  2  3  4  5  7  Routing Table Destination  0	Path 6310 631 62 63 624 6315 6317 for Node Path 60	Cost 11 7 6 3 12 20 22 no. 6 Cost 12			20	Destinat  0  1  2  3  4  5  6  Routing  Destinat  0	tion Table	Pa 70 71 71 70 70 71 for Pa 70	th 2 3 4 5 36 Node th	Cost 15 15 18 19 18 30 22 no. 7 Cost 12			
Destination  1 2 3 4 5 7 Routing Table Destination 0	Path 6310 631 62 63 624 6315 6317 for Node Path 60 631	Cost 11 7 6 3 12 20 22 no. 6 Cost 12 9			20	Destinat  0  1  2  3  4  5  6  Routing Destinat  0  1	tion Table	Pa 70 71 71 70 70 71 for Pa 70	th 2 3 4 5 36 Node th	Cost 15 15 18 19 18 30 22 no. 7 Cost 12 18			
Destination  1 2 3 4 5 7 Routing Table Destination 0	Path 6310 631 62 63 624 6315 6317 for Node Path 60 631 62	Cost 11 7 6 3 12 20 22 no. 6 Cost 12 9 6			20	Destinat  0  1  2  3  4  5  6  Routing Destinat  0  1	tion Table	Pa 70 71 71 70 70 71 for Pa 70 70	th 2 3 4 5 36 Node th	Cost 15 15 18 19 18 30 22 no. 7 Cost 12 18 21			
Destination  1 2 3 4 5 7 Routing Table Destination 0	Path 6310 631 62 63 624 6315 6317 for Node Path 60 631 62 63	Cost 11 7 6 3 12 20 22 no. 6 Cost 12 9 6 5			20	Destinate 0 1 2 3 4 5 6 Routing Destinate 0 1 2	tion Table	Pa 70 71 71 70 70 71 for Pa 70 70 70	th 2 3 4 5 36 Node th	Cost 15 15 18 19 18 30 22 no. 7 Cost 12 18 21 21			
Destination  1 2 3 4 5 7 Routing Table Destination 0 1 2 3 4	Path 6310 631 62 63 624 6315 6317 for Node Path 60 631 62 63 624	Cost 11 7 6 3 12 20 22 no. 6 Cost 12 9 6 5			20	Destinate 0 1 2 3 4 5 6 Routing Destinate 0 1 2 3 4	tion Table	Pa 70 71 71 70 70 71 for Pa 70 70 70	th 2 3 4 5 36 Node th 1 2 3	Cost 15 15 18 19 18 30 22 no. 7 Cost 12 18 21 21 17			
Destination  1 2 3 4 5 7 Routing Table Destination 0 1 2 3 4 5	Path 6310 631 62 63 624 6315 6317 for Node Path 60 631 62 63 624 605	Cost 11 7 6 3 12 20 22 no. 6 Cost 12 9 6 5 10 27			20	Destinate 0 1 2 3 4 5 6 Routing Destinate 0 1 2 3 4	tion Table	Pa 70 71 71 70 70 71 for Pa 70 70 70 70	th 2 3 4 5 36 Node th 1 2 3 4	Cost 15 15 18 19 18 30 22 no. 7 Cost 12 18 21 21 17 27			
Destination  1 2 3 4 5 7 Routing Table Destination 0 1 2 3 4	Path 6310 631 62 63 624 6315 6317 for Node Path 60 631 62 63 624	Cost 11 7 6 3 12 20 22 no. 6 Cost 12 9 6 5			20	Destinate 0 1 2 3 4 5 6 Routing Destinate 0 1 2	tion Table	Pa 70 71 71 70 70 71 for Pa 70 70 70 70	th 2 3 4 5 36 Node th 1 2 3	Cost 15 15 18 19 18 30 22 no. 7 Cost 12 18 21 21 17			

Figure 4: Routing tables for the second topology (continued...)

#### 4.3 Observations

As we can observe, the paths and costs have been changing as time passes. This is one of the advantages that OSPF has. It can adjust the routing tables to accommodate for the changing network conditions. And the process is quick too as the LSA packets flood the network very quickly with the cost of some network overhead.

### 5 Learnings

This assignment has been helpful in

- Learning some insights about the OSPF protocol and how routing in general works.
- Learning Bash scripting and basic threading in C++.

#### 6 Conclusion

OSPF is a widely deployed routing protocol that can converge a network in a few seconds and guarantee loop-free paths. Having a quick routing protocol that is adaptive to the network conditions is vital to maintain efficient communication within the network. With this assignment, we have gained insights into how the algorithm works by emulating how the communications occur between the routers.

## 7 References

• https://en.wikipedia.org/wiki/Open\_Shortest\_Path\_First