Project **III**

Optimize Content-Centric Networking

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Office Hour: 15:00 - 18:00 Monday

13:00 - 18:00 Wednesday

At 95521 CPS Lab or **LINE** or **Email**

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2021.05.05

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Outline

- **Project 3**
- **CCN construction**
- **Format**
- **Test data**
- **Output_interest and Output_data**
- **Process Flow**
- **Coding**

1. Project 3

- You should optimize this CCN network based on **project 2**.
- **1. Add cs.py and fib.py to CCN**

  interest.py、data.py、forward.py、ps.py、pit.py、cs.py、fib.py .....

- **2. Creat two tables**

  Queue、PS、PIT、CS、FIB

Tip:

In Project 3, CS and FIB are used to optimize CCN. That is to say, the interest packet goes to the PS to find whether there is matching content data, and also to the CS to find whether there is matching content data. CS does cache the content data in the data packet.

FIB is recorded routing information of data packet.

When the interest packet needs to be forwarded, it is sent to all its neighbors by broadcasting, and you can read the network to obtain neighbor connection information.

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1. Project 3

- **Optimization**
- Interest_queue and data_queue

Their storage size is limited. In addition, the router takes the first packet to process each time.

When the queue is full, you need to optimize how to update records. (FIFO, LRU, LFU, etc.)

- CS

The cache size of CS is limited. When the CS is full, you need to optimize how to update records. (FIFO, LRU, LFU, Cost-based or Time-based etc.)

1. Project 3

- **3. Performance evaluation parameters**

$$\text{Cache hit rate} = \frac{\text{The total number of interest hit in CS}}{\text{The total number of interest (hit + miss) in CS}}$$

$$\text{Average response time} = \frac{\text{The total response time of interest}}{\text{The total number of interest sent by consumer}}$$

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1. Project 3

- **3. Test CCN simulator**

  Input

  read 'peremiters、networks、interests、contents of producer' **json** files.

  run your CCN simulator.

  Output

  real-time output packets information to save in csv files (**interest.csv** and **data.csv**).

  interest =

["Time"=str(int(time.time()-interest['run_start_time']), "Type"=interest['type'], "Interest_ID"='I'+str(interest['interest_ID']),"Consumer_ID"='C'+str(interest['consumer_ID']), "Route_ID"='R'+str(interest['route_ID']), "Content_name"=interest['content_name'], "Interest_hop"=interest['interest_hop'], "Path"=interest['path'], "Result"='Interest hit in CS', "Hit_cs"=1, "Miss_cs"=0, "interest_number"=0]

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1. Project 3

- **3. Test CCN simulator**

  Input

  read 'peremiters、networks、interests、contents of producer' **json** files.

  run your CCN simulator.

  Output

  real-time output packets information to save in csv files (**interest.csv** and **data.csv**).

  data =

["Time"=str(times-data['run_start_time']), "Type"=data['type'], "Consumer_ID"='C'+str(data['consumer_ID']), "Route_ID"='R'+str(data['route_ID']), "Content_name"=data['content_name'], "Data_hop"=data['data_hop'], "Path"=data['path'], "Result"='Data hit in consumer', "Hit_consumer"=1, "Hit_PIT"=1, "Hit_Miss"=0, "response_time"= current_time -interest_start_time]

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1. Project 3

- **Code**

  python

- **Upload**

  2021.06.16 10:00 am upload to moodle

- **Filename**

  project3_group1_V1.rar

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1. Project 3

- **DEMO**
  - **Time:** 2021.06.16
  - **Location:** 95519 room

  - Explain what optimizations you made.
  - Run your simulator and output the cache hit rate and average response time.

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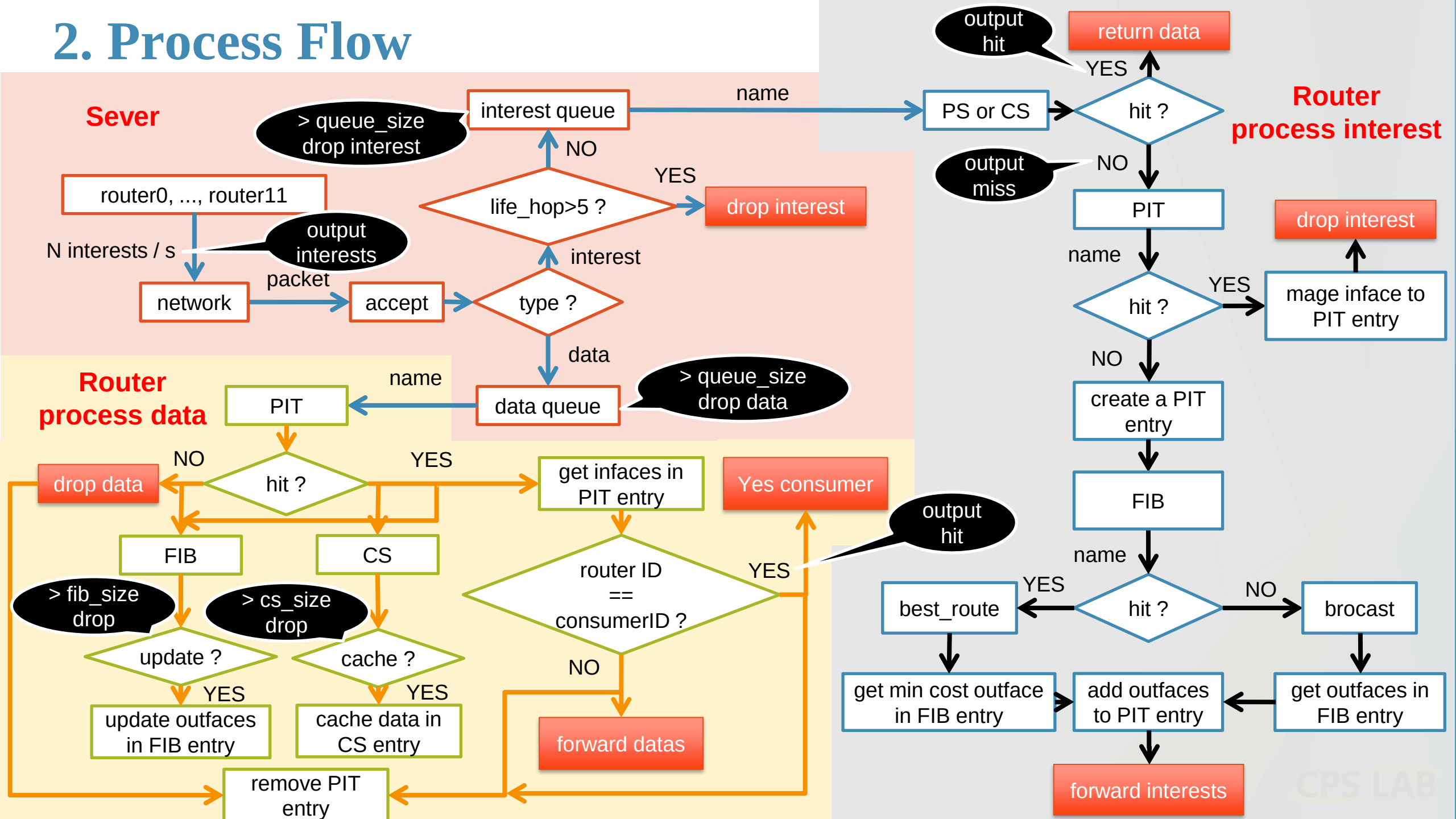
2. Process Flow



3. CCN construction

- **main.py**
- sever.py
- **network.py**

- **ps.py**
- **pit.py**
- **cs.py**
- **fib.py**

- interest.py
- data.py
- forward.py

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4. Format

- Interest packets received by router

interest = *{'type': 'interest', 'interest_ID': 0000, 'consumer_ID': 0, 'route_ID': 0, 'content_name': 'r0/00', 'interest_hop': 0, 'life_hop': 5, 'run_start_time': 0, 'path': 'p0/', 'interest_start_time': 0}*

- You need to add a *'interest_start_time'* field in the *interest packet*
- *'interest_start_time':* The time when the consumer sends out the *interest packet*. It will be used to calculate the response time for the consumer to receive the data.

response time = current time - interest_start_time

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4. Format

- Data packets received by router

data = *{'type': 'data', 'consumer_ID': 0000, 'route_ID': 0, 'content_name': 'r0/00', 'content_data': 'r0/000', 'data_hop': 0, 'run_start_time': 0, 'path': 'p0/', 'interest_start_time': 0, 'data_start_time': 0}*

- You need to add a *'interest_start_time'* and *'data_start_time'* field in the *data packet*
- *'interest_start_time' = interest['interest_start_time']*
- *'data_start_time':* The time when the router sends out the *interest packet*. It is the time when the *router* that obtained *content data* created the *data packet*. It will be used to calculate the travel time of *data packet*.

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4. Format

- **cs** = *[[content_name, data, time, cost], ...]*
- **cs_entry** = *[content_name, data, time, cost]*
- **fib** = *{'content_name': [[outface, cost, time], ...], ... }*
- **fib_entry** = *[[outface, cost, time], ...]*

Tip:

CS and *FIB* will be used in project 3, you must to add its. Each router has these tables independently.

time: The time when the *data* was recorded in the *CS* or *FIB*.

cost: The cost is the *data_hop* or *travel time* of the *data packet*.

$$\text{travel time} = \text{current time} - \text{data\_start\_time}$$

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4. Format

- interest hit in *PS* or *CS*
- Create a *data packet*, the format is as follows

data packet =

[[5, {'type': 'data', 'consumer_ID': 0, 'route_ID': 4, 'content_name': 'r4/01', 'content_data': 'r4/011615357625', 'data_hop': 1, 'run_start_time': 1615357618, 'path': 'p4/', 'interest_start_time': 1615357620, 'data_start_time': 1615357634}]]

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4. Format

- interest miss in *PS* or *CS*

Create forwarding *interest packets*, which may need to be forwarded to multiple *outgoing interfaces*. The first number of each list is the *outgoing interface* (*router ID*). The format is as follows

interest packets =

*[[**3**, {'type': 'interest', 'interest_ID': '0001', 'consumer_ID': 0, 'route_ID': 5, 'content_name': 'r7/07', 'interest_hop': 3, 'life_hop': 5, 'start_time': 1615357599, 'path': 'p0/3/5', 'interest_start_time': 1615357620, 'data_start_time': 1615357634}],*

*[**4**, {'type': 'interest', 'interest_ID': '0001', 'consumer_ID': 0, 'route_ID': 5, 'content_name': 'r7/07', 'interest_hop': 3, 'life_hop': 5, 'start_time': 1615357599, 'path': 'p0/3/5', 'interest_start_time': 1615357620, 'data_start_time': 1615357634}],*

*[**5**, {'type': 'interest', 'interest_ID': '0001', 'consumer_ID': 0, 'route_ID': 5, 'content_name': 'r7/07', 'interest_hop': 3, 'life_hop': 5, 'start_time': 1615357599, 'path': 'p0/3/5', 'interest_start_time': 1615357620, 'data_start_time': 1615357634}]]*

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4. Format

- data hit in PIT

Create forwarding *data packets*, which may need to be forwarded to multiple *incoming interfaces*. The first number of each list is the *incoming interface* (*router ID*). The format is as follows

data packets =

[[2, {'type': 'data', 'consumer_ID': 0, 'route_ID': 4, 'content_name': 'r5/09', 'content_data': 'r5/091615357623', 'data_hop': 2, 'start_time': 1615357615, 'path': 'p5/4/', 'interest_start_time': 1615357620, 'data_start_time': 1615357634}],

[6, {'type': 'data', 'consumer_ID': 0, 'route_ID': 4, 'content_name': 'r5/09', 'content_data': 'r5/091615357623', 'data_hop': 2, 'start_time': 1615357615, 'path': 'p5/4/', 'interest_start_time': 1615357620, 'data_start_time': 1615357634}]]

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5. Test data

- **networks**
- json={

  "r0":[1, 3],

  "r1": [0, 2, 3],

  "r2": [1, 4],

  ...

  "r11": [7, 10]

}

Tip:

The key is the *router ID* of **string type**. The value is a list, and the numbers in the list are the **numeric type** of the *router ID*.

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5. Test data

- **parameters**
- json={*"route_num": 12,* # number of routers

  "frequency": 2, # **2 new interest packet / second** sent by each router to network

  "content_num": 100, # number of content published by each producer

  "run_time": 100, # Simulator running time

  "queue_size": 10, # number of packet stored in the queue

  "cache_size": 10, # number of content data stored in cs

  "FIB_size": 50} # number of entry stored in the fib

Tip:

In project 3, when the queue is **full**, the newly received packet is **droped**.

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5. Test data

- **producer_contents**

  12 note *100 content =1200 total

- json={

  "r0": ["r0/0", "r0/1", "r0/2", ..., "r0/98", "r0/99"],

  "r1": ["r1/0", "r1/1", "r1/2", ..., "r1/98", "r1/99"],

  "r2": ["r2/0", "r2/1", "r2/2", ..., "r2/98", "r2/99"],

  ...

  "r11": ["r11/0", "r11/1", "r11/2", ..., "r11/98", "r11/99"]

  }

Tip:

The key is the *router ID* of **string type**. The value is a list containing one **100 *content names*** prefixed with its own *router ID*.

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5. Test data

- **interests**
- 5 interest/s*12 = 60 interest/s 12*100 interest=1200 interests
- json={

  "r0": [{'interest_ID': 0000,'content_name':'r1/3'}, ...],

  "r1": [{'interest_ID': 1000,'content_name':'r9/2'}, ...],

  "r2": [{'interest_ID': 2000,'content_name':'r11/8'}, ...],

  ...

  "r11": [{'interest_ID': 1100,'content_name':'r6/7'}, ...]

  }

Tip:

The key is the *router ID* of **string type**. The value is a list containing one **100** *interest packets*. Each *interest packet* is a **dictionary** containing *interest_ID* and *content_name*.

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5. Test data

- **interests**
- 5 interest/s*12 = 60 interest/s 12*100 interest=1200 interests
- json={

  "r0": [{'interest_ID': 0000,'content_name':'r1/3'}, ...],

  "r1": [{'interest_ID': 1000,'content_name':'r9/2'}, ...],

  "r2": [{'interest_ID': 2000,'content_name':'r11/8'}, ...],

  ...

  "r11": [{'interest_ID': 1100,'content_name':'r6/7'}, ...]

  }

Tip:

interest_ID = routerID + 00-99

content_name is randomly selected from 1200 *content* published by 12 producers. Therefore, some *content names* may be repeatedly selected.

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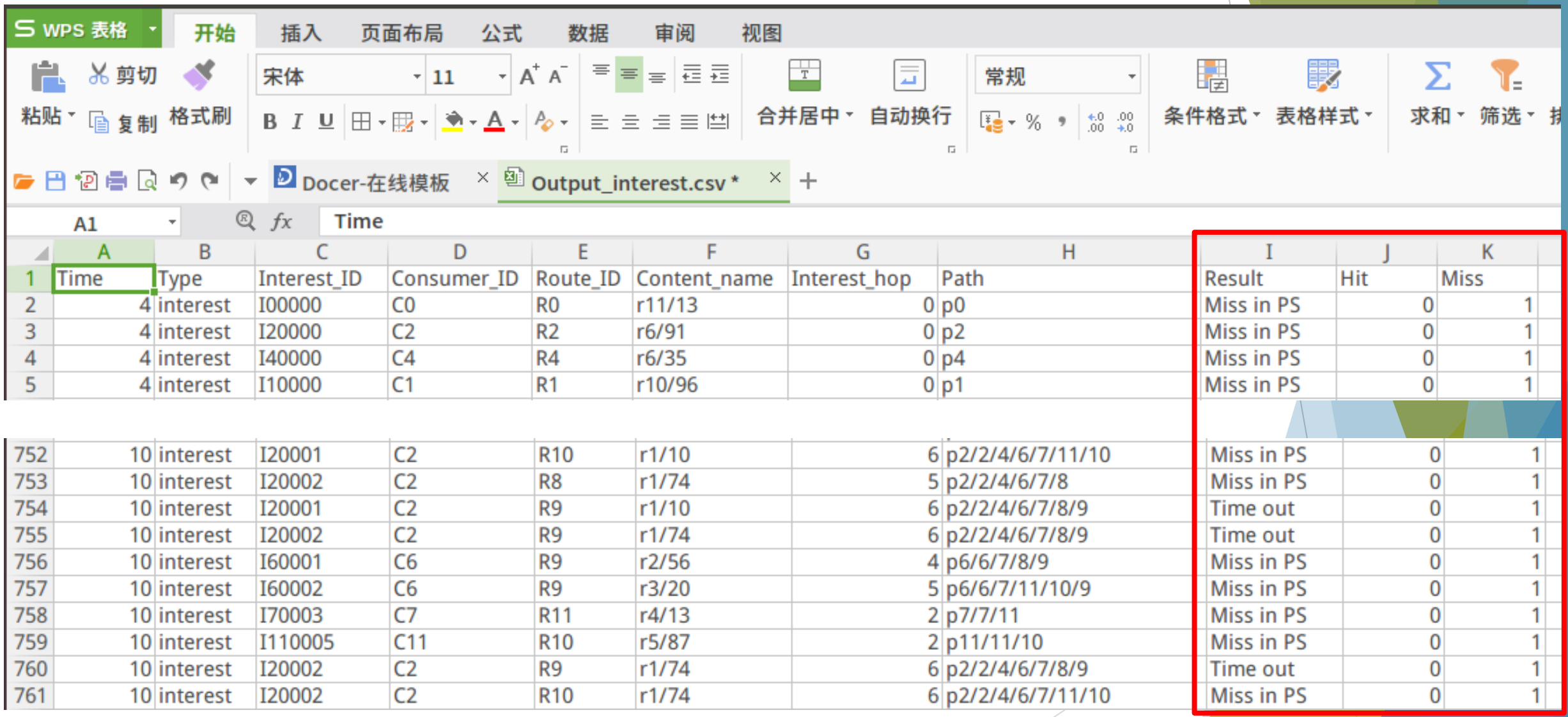
6. Output_interest



WPS 表格 | 开始 | 插入 | 页面布局 | 公式 | 数据 | 审阅 | 视图

Docer-在线模板 | Output_interest.csv *

A1 | Time

	A	B	C	D	E	F	G	H	I	J	K
1	Time	Type	Interest_ID	Consumer_ID	Route_ID	Content_name	Interest_hop	Path	Result	Hit	Miss
2	4	interest	I00000	C0	R0	r11/13	0	p0	Miss in PS	0	1
3	4	interest	I20000	C2	R2	r6/91	0	p2	Miss in PS	0	1
4	4	interest	I40000	C4	R4	r6/35	0	p4	Miss in PS	0	1
5	4	interest	I10000	C1	R1	r10/96	0	p1	Miss in PS	0	1
752	10	interest	I20001	C2	R10	r1/10	6	p2/2/4/6/7/11/10	Miss in PS	0	1
753	10	interest	I20002	C2	R8	r1/74	5	p2/2/4/6/7/8	Miss in PS	0	1
754	10	interest	I20001	C2	R9	r1/10	6	p2/2/4/6/7/8/9	Time out	0	1
755	10	interest	I20002	C2	R9	r1/74	6	p2/2/4/6/7/8/9	Time out	0	1
756	10	interest	I60001	C6	R9	r2/56	4	p6/6/7/8/9	Miss in PS	0	1
757	10	interest	I60002	C6	R9	r3/20	5	p6/6/7/11/10/9	Miss in PS	0	1
758	10	interest	I70003	C7	R11	r4/13	2	p7/7/11	Miss in PS	0	1
759	10	interest	I110005	C11	R10	r5/87	2	p11/11/10	Miss in PS	0	1
760	10	interest	I20002	C2	R9	r1/74	6	p2/2/4/6/7/8/9	Time out	0	1
761	10	interest	I20002	C2	R10	r1/74	6	p2/2/4/6/7/11/10	Miss in PS	0	1

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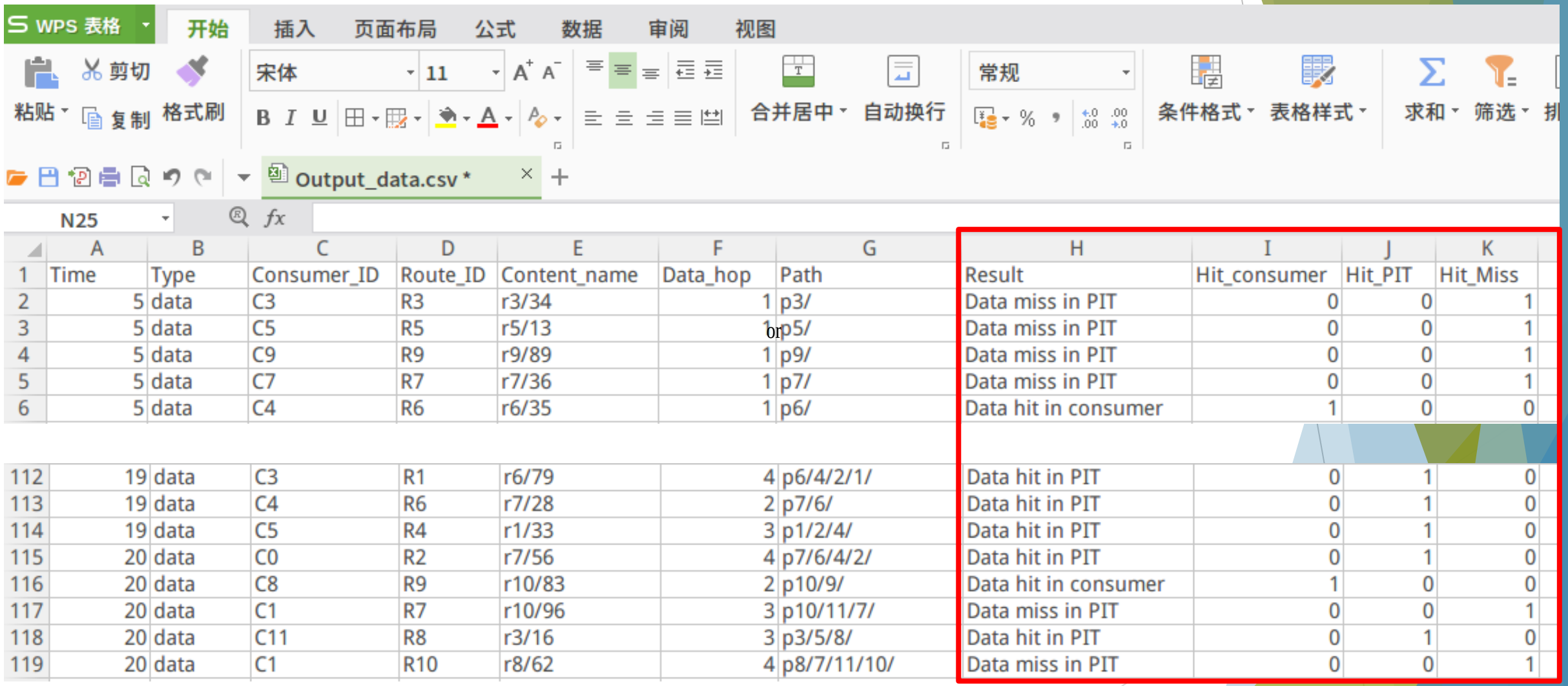
6. Output_data



WPS 表格 | 开始 | 插入 | 页面布局 | 公式 | 数据 | 审阅 | 视图

Output_data.csv *

N25

	A	B	C	D	E	F	G	H	I	J	K
1	Time	Type	Consumer_ID	Route_ID	Content_name	Data_hop	Path	Result	Hit_consumer	Hit_PIT	Hit_Miss
2	5	data	C3	R3	r3/34	1	p3/	Data miss in PIT	0	0	1
3	5	data	C5	R5	r5/13	1	p5/	Data miss in PIT	0	0	1
4	5	data	C9	R9	r9/89	1	p9/	Data miss in PIT	0	0	1
5	5	data	C7	R7	r7/36	1	p7/	Data miss in PIT	0	0	1
6	5	data	C4	R6	r6/35	1	p6/	Data hit in consumer	1	0	0
112	19	data	C3	R1	r6/79	4	p6/4/2/1/	Data hit in PIT	0	1	0
113	19	data	C4	R6	r7/28	2	p7/6/	Data hit in PIT	0	1	0
114	19	data	C5	R4	r1/33	3	p1/2/4/	Data hit in PIT	0	1	0
115	20	data	C0	R2	r7/56	4	p7/6/4/2/	Data hit in PIT	0	1	0
116	20	data	C8	R9	r10/83	2	p10/9/	Data hit in consumer	1	0	0
117	20	data	C1	R7	r10/96	3	p10/11/7/	Data miss in PIT	0	0	1
118	20	data	C11	R8	r3/16	3	p3/5/8/	Data hit in PIT	0	1	0
119	20	data	C1	R10	r8/62	4	p8/7/11/10/	Data miss in PIT	0	0	1

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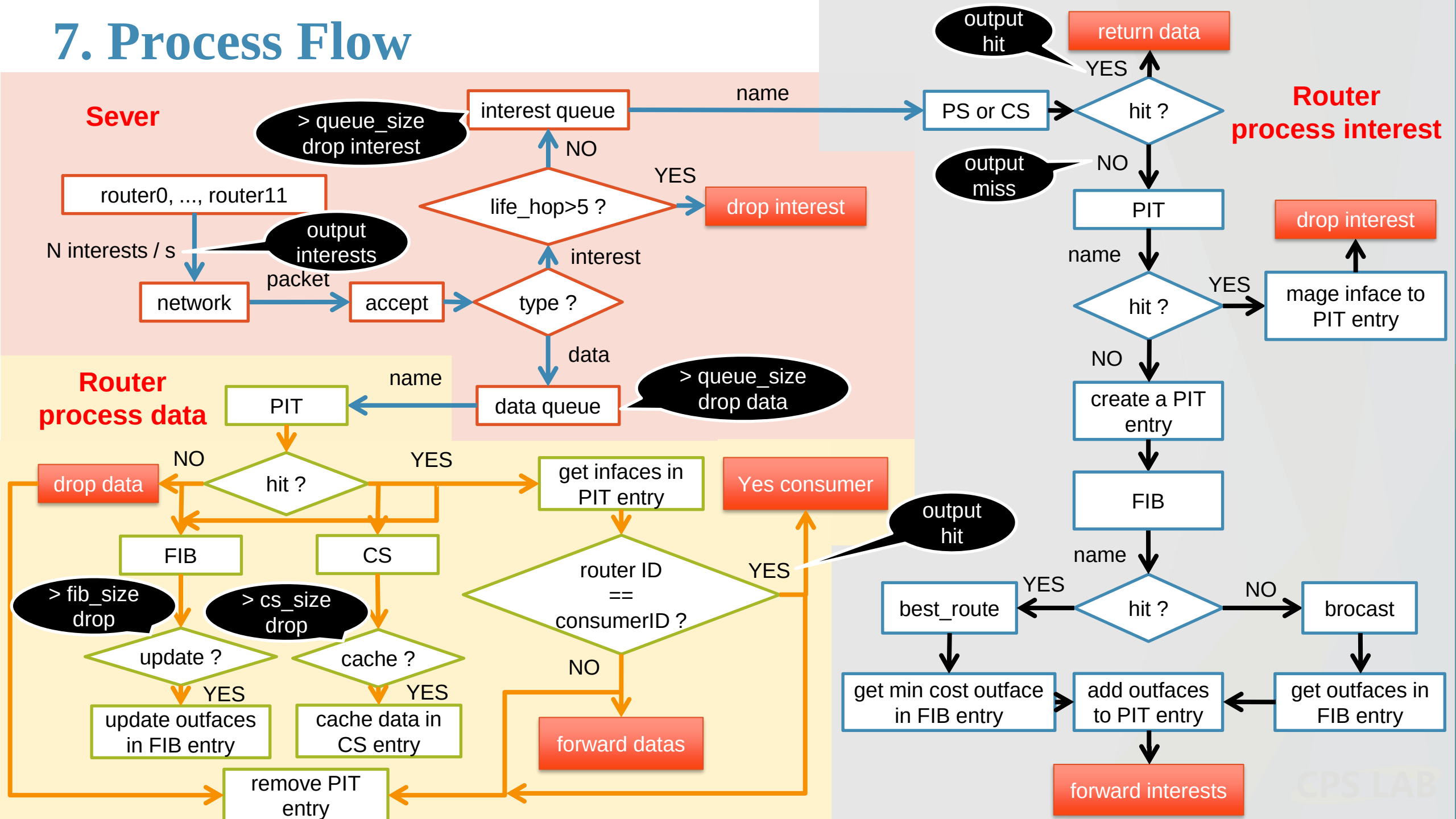
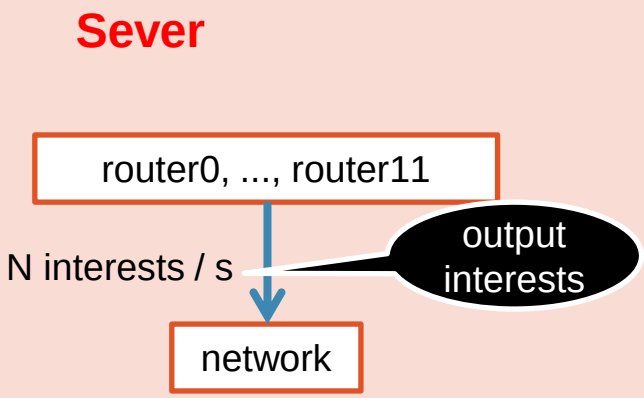
7. Process Flow



7. Process Flow



Sever process

- The network has 12 node. You can read from the **networks** JSON file .
- networks format

= *{'r'+'route_ID': [route_ID, ...], ... }*

= *{'r1': [0, 2], 'r2': [1, 3, 4], ... }*

- Each node is both a **producer** and a **consumer**.
- **router ID** = **consumer ID =** *0 1 ... 11*
- As a **producer**, router0 will publish the *content name* with its own router name prefix, for example *'r0/'*. Each producer publishes 100 pieces of content, such as *'r0/00-99'*. You can read from the **producer_contents** JSON file .
- producer_contents format

= *{'r'+'route_ID': [content_name, ...], ... }*

= *{'r0': ['r0/00', 'r0/01', ..., 'r0/99'], 'r1': ['r1/00', 'r1/01', ..., 'r1/99'], ... }*

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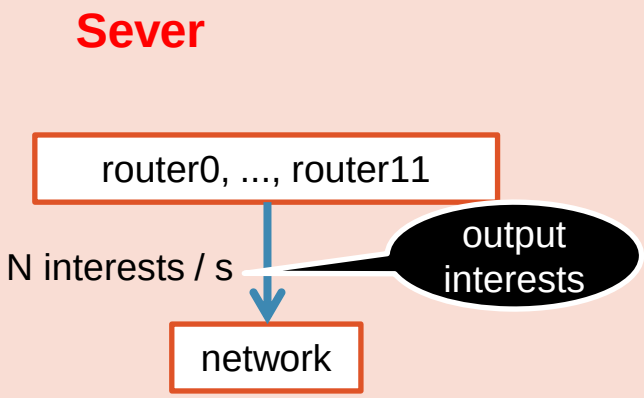
7. Process Flow



Sever process

- As a **consumer**, router1can send out *interest packet* to request any content name with a router name prefix, such as *'r1/88'*.
- All routers simultaneously send out ***N*** **new interests / s** to the network.
- *N = frequency*. You can read from the **parameters** and **interests** JSON file based on the *router name*. *interests* has only *interest_ID* and *content name*. You need to fill in other information according to the complete format of the *interest*.
- interests format

={"r0": [{'interest_ID': 0000,'content_name':'r1/3'}, ...], "r1": [{'interest_ID': 1000,'content_name':'r9/2'}, ...], ... "r11": [{'interest_ID': 1100,'content_name':'r6/7'}, ...]}

- interest format

= {'type': 'interest', 'interest_ID': 0000, 'consumer_ID': 0, 'route_ID': 0, 'content_name': 'r0/00', 'interest_hop': 0, 'life_hop': 5, 'run_start_time': 0.0, 'path': 'p0/', 'interest_start_time': 1615357620, 'data_start_time': 1615357634}

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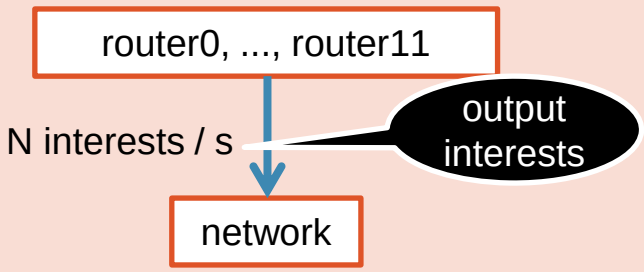
7. Process Flow



- **Sever process**
- You need to output the number of *interest packets* sent by each consumer. So that you can calculate the average response time.

- Interest Output.CSV format

= [

"Time"=str(int(time.time()-interest['run_start_time']), "Type"=interest['type'], "Interest_ID"='I'+str(interest['interest_ID']), "Consumer_ID"='C'+str(interest['consumer_ID']), "Route_ID"='R'+str(interest['route_ID']), "Content_name"=interest['content_name'], "Interest_hop"=interest['interest_hop'], "Path"=interest['path'],"Result"='Send Interest by Consumer', "Hit_cs"=0,"Miss_cs"=0, "interest_number"=5, "response_time"=0

]

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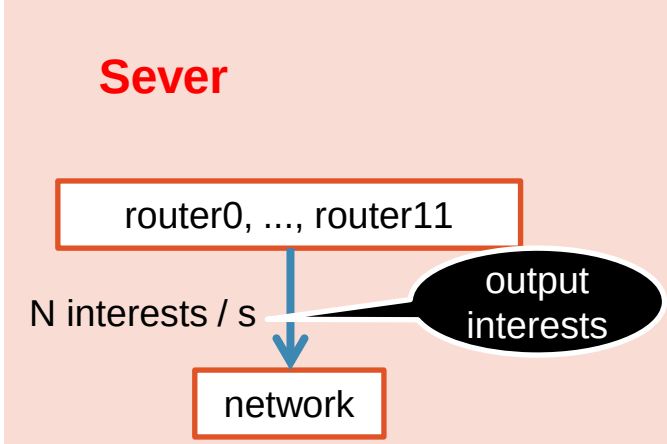
7. Process Flow



- **Sever process**
- Get N in turn from the *interests* belonging to this router. And package them *start_packets*, and then hand them to the server to send them to the network.
- Interest packets format sent by consumer
- start_packets

= [{'type': 'interest', 'interest_ID': '0300', 'consumer_ID': 3, 'route_ID': 3, 'content_name': 'r7/01', 'interest_hop': 0, 'life_hop': 5, 'run_start_time': 1615357629, 'path': 'p3/', 'interest_start_time': 1615357620, 'data_start_time': 1615357634},

.....

{'type': 'interest', 'interest_ID': '0304', 'consumer_ID': 3, 'route_ID': 3, 'content_name': 'r11/8', 'interest_hop': 0, 'life_hop': 5, 'run_start_time': 1615357629, 'path': 'p3/', 'interest_start_time': 1615357620, 'data_start_time': 1615357634}]

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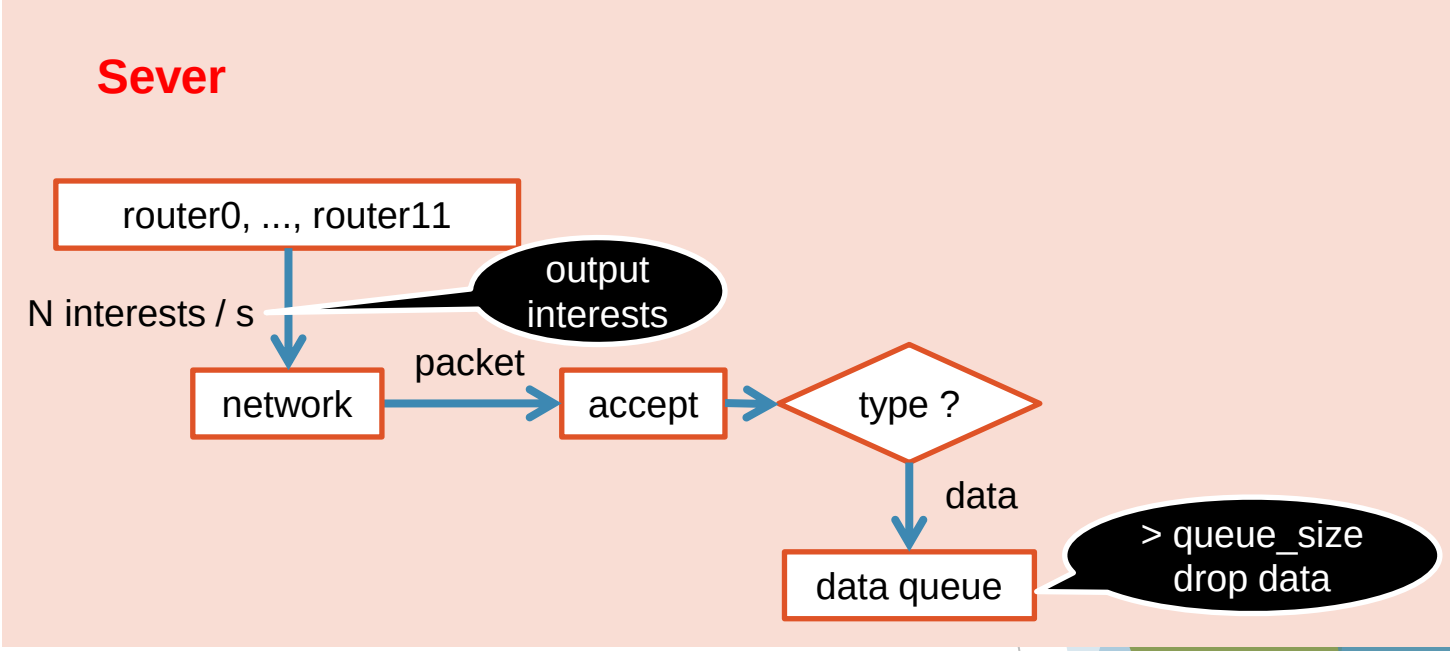
7. Process Flow

Sever process

- When the accept receives a *packet*, it needs to read the *type* of *packet* and determine whether it is *interest* or *data*.



- If it is a *data packet*, you need to determine whether the *data_queue* size is greater than the *queue_size*. You can read the *queue_size* from the **parameter** JSON file.
- If it is YES, it indicates that the *data_queue* is full, and the received *packet* is droped and not stored in the *data_queue*.
- If NO, then store the received *packet* in the *data_queue*.
- Their storage size is limited. In addition, the router takes the first packet to process each time.
- When the queue is full, you need to optimize how to update records. (FIFO, LRU, LFU, etc.)

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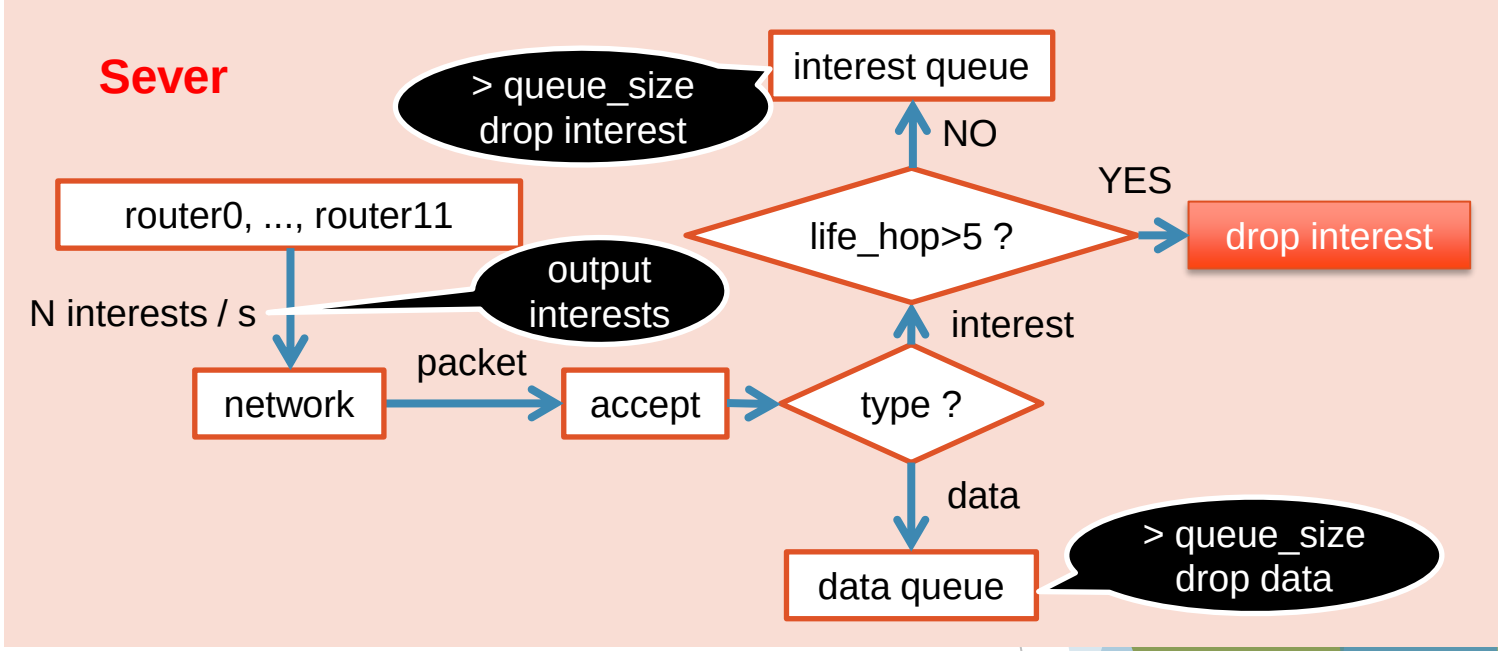
7. Process Flow



- **Sever process**
- If it is a *interest packet*, you need to read the *life_hop* from the *packet*.
- Then see if it is greater than 5. If YES, then drop the *interest packet*. Because we set an *interest packet* to have a life cycle of only 5 hops in the network.
- If NO, you need to determine whether the *interest_queue* size is greater than the *queue_size*. You can read the *queue_size* from the **parameter** JSON file.
- If it is YES, it indicates that the *interest_queue* is full, and the received *packet* is droped and not stored in the *interest_queue*.
- If NO, then store the received *packet* in the *interest_queue*.
- Their storage size is limited. In addition, the router takes the first packet to process each time.
- When the queue is full, you need to optimize how to update records. (FIFO, LRU, LFU, etc.)

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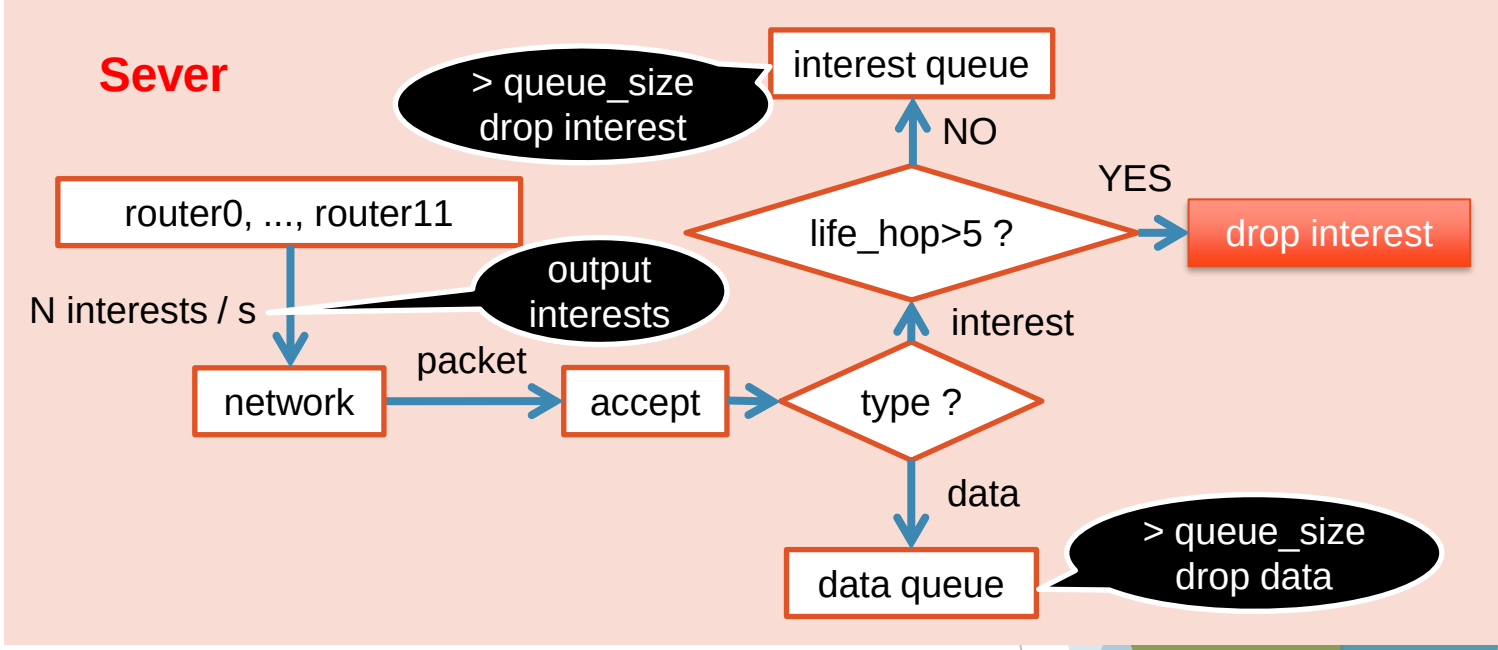
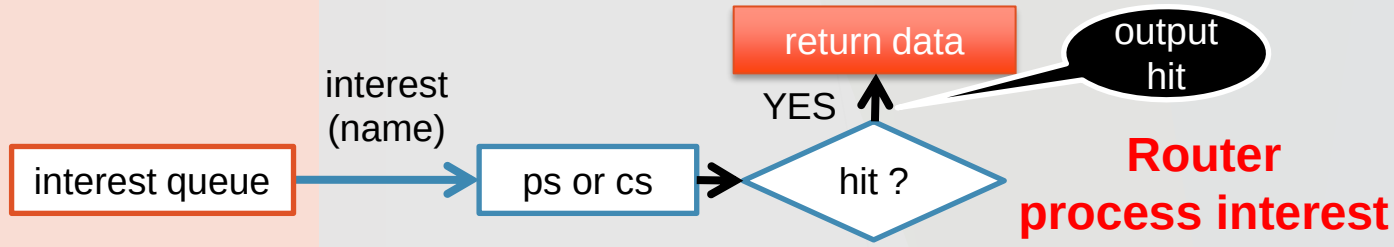
7. Process Flow

- **Sever process**
- After the simulator runs for a fixed period of time, it exits. You can read *run_time* from the **parameters** JSON file.
- The server monitors whether a *packet* is received in real time.
- The router takes the first *packet* from the *interest_queue* and *data_queue* for processing each time.



CPS LAB

7. Process Flow



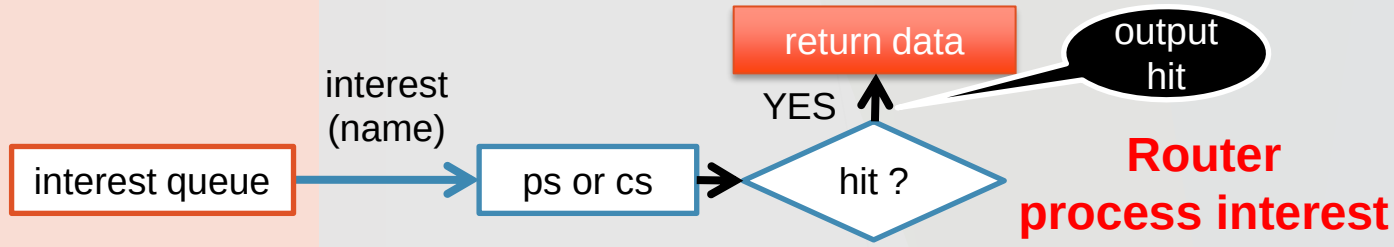
Interest process

- The router takes the first *packet* from the *interest_queue* for processing each time.
- The router gets *name* from packet. Go to ***ps*** *(producer store)* to find if there is matching *data*.
- ***ps*** stores 100 content published by each producer, such as *'r0/00-99'*. You can read from the **producer_contents** JSON file.
- ***ps*** format

= *[content_name, ...]*

- If it hits, *data packet* is returned.

7. Process Flow



- **Interest process**
- If it miss, go to ***cs*** *(cache store)* to find if there is matching *data*. ***cs*** can cache the *content data* of *data packet*.
- ***cs*** format

= *[[content_name, data, time, cost], ...]*

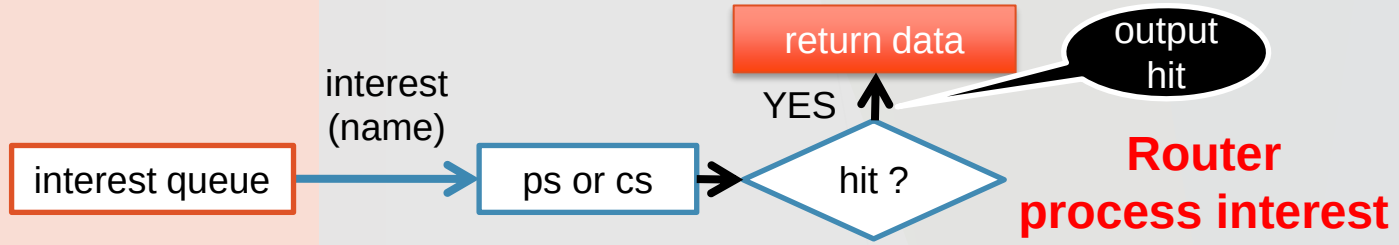
- **cs_entry**

= *[content_name, data, time, cost]*

- ***time:*** The time when the *data* was recorded in the *CS*.
- ***cost:*** It is the *data_hop* or travel time of the *data packet*.

☆ If it hits, *data packet* is returned.

7. Process Flow



Interest process

- Create a data packet.
- *data packet* format

= [[5, {'type': 'data', 'consumer_ID': 0, 'route_ID': 9, 'content_name': 'r9/01', 'content_data': 'content_name' + str(current time), 'data_hop': 1, 'run_start_time': 1615357618, 'path': 'p9/', 'interest_start_time': 0, 'data_start_time': 0}]]

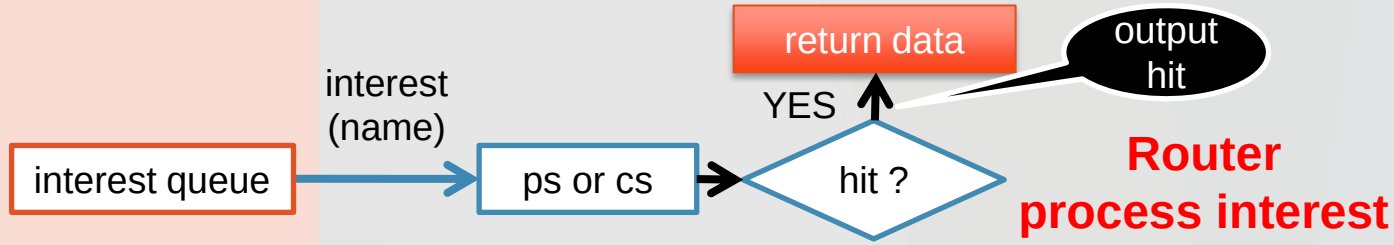
- The first element 5 of the list represents the *incoming interface* (it is *router_ID* in *interest*) of the *interest*.
- The second element of the list is a dictionary, which represents a *data packet*.
- *content_data* format

= 'content_name' + str(current time)

'interest_start_time' = interest['interest_start_time']

'data_start_time' = str(current time)

7. Process Flow



- **Interest process**
- Output 'Interest hit in CS' to CSV.
- Interest Output.CSV format

= ["Time"=str(int(time.time()-interest['run_start_time']),
"Type"=interest['type'],

"Interest_ID"='I'+str(interest['interest_ID']),
"Consumer_ID"='C'+str(interest['consumer_ID']),
"Route_ID"='R'+str(interest['route_ID']),

"Content_name"=interest['content_name'],

"Interest_hop"=interest['interest_hop'],
"Path"=interest['path'],

"Result"='Interest hit in CS',

"Hit_cs"=1, "Miss_cs"=0,

"interest_number"=0]

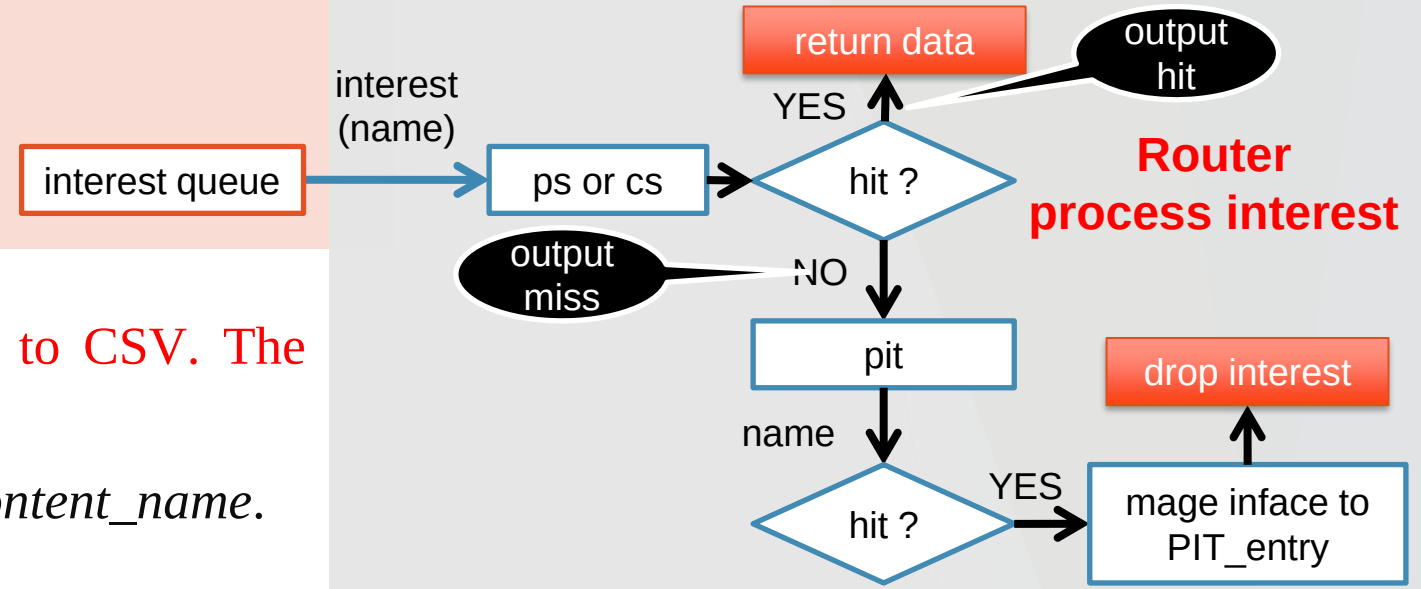
7. Process Flow

- **Interest process**
- If miss in ***cs***, output *'Interest miss in CS'* to CSV. The format following above.
- And go to *pit* to find a matching *entry* by *content_name*.
- ***pit*** format

= *{'content_name': [[inface, ...], [outface, ...]], ... }*

- ***PIT_entry*** format

= *[[inface, ...], [outface, ...]]*



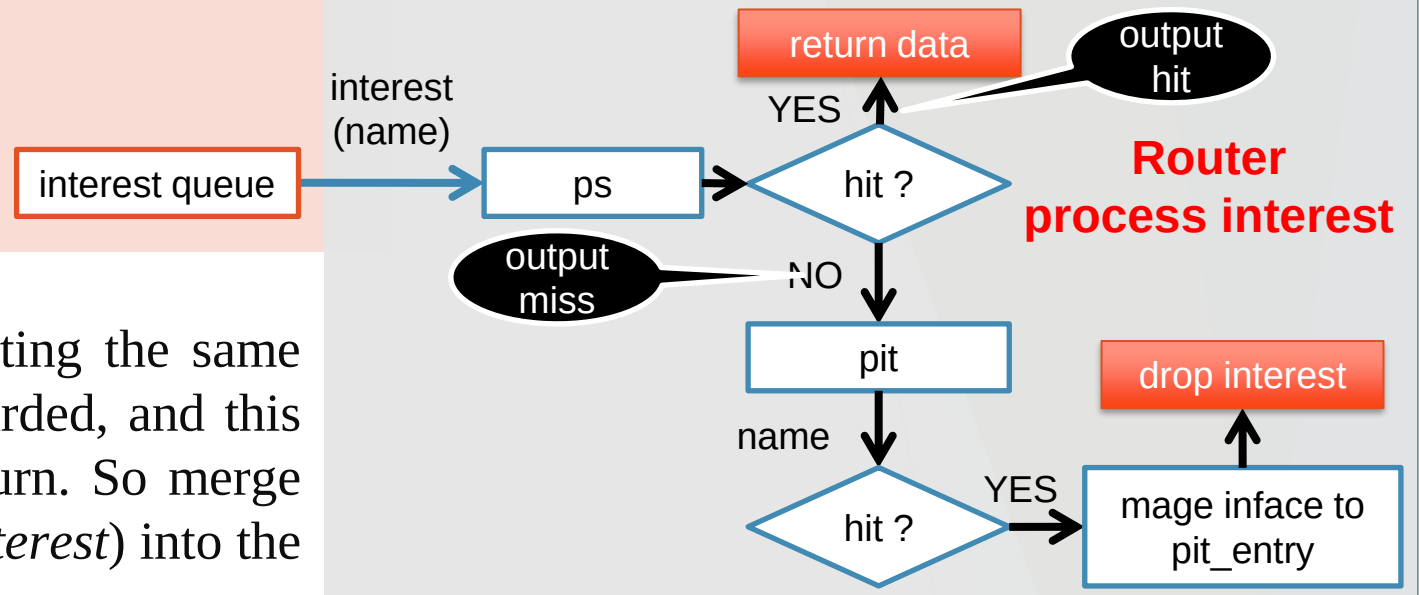
7. Process Flow

Interest process

- If it hits, it means that the *interest* requesting the same *content name* has been received and forwarded, and this *interest* only needs to wait for *data* to return. So merge the *incoming interface* (it is *router_ID* in *interest*) into the *inface* of entry.
- ***PIT_entry*** format

= *[[inface, ...], [outface, ...]]*

- You may want to check to make sure that there is no duplicate *inface* in *PIT_entry* .
- And then drop the *interest*. The router takes a *data packet* from the *data_queue* for processing.



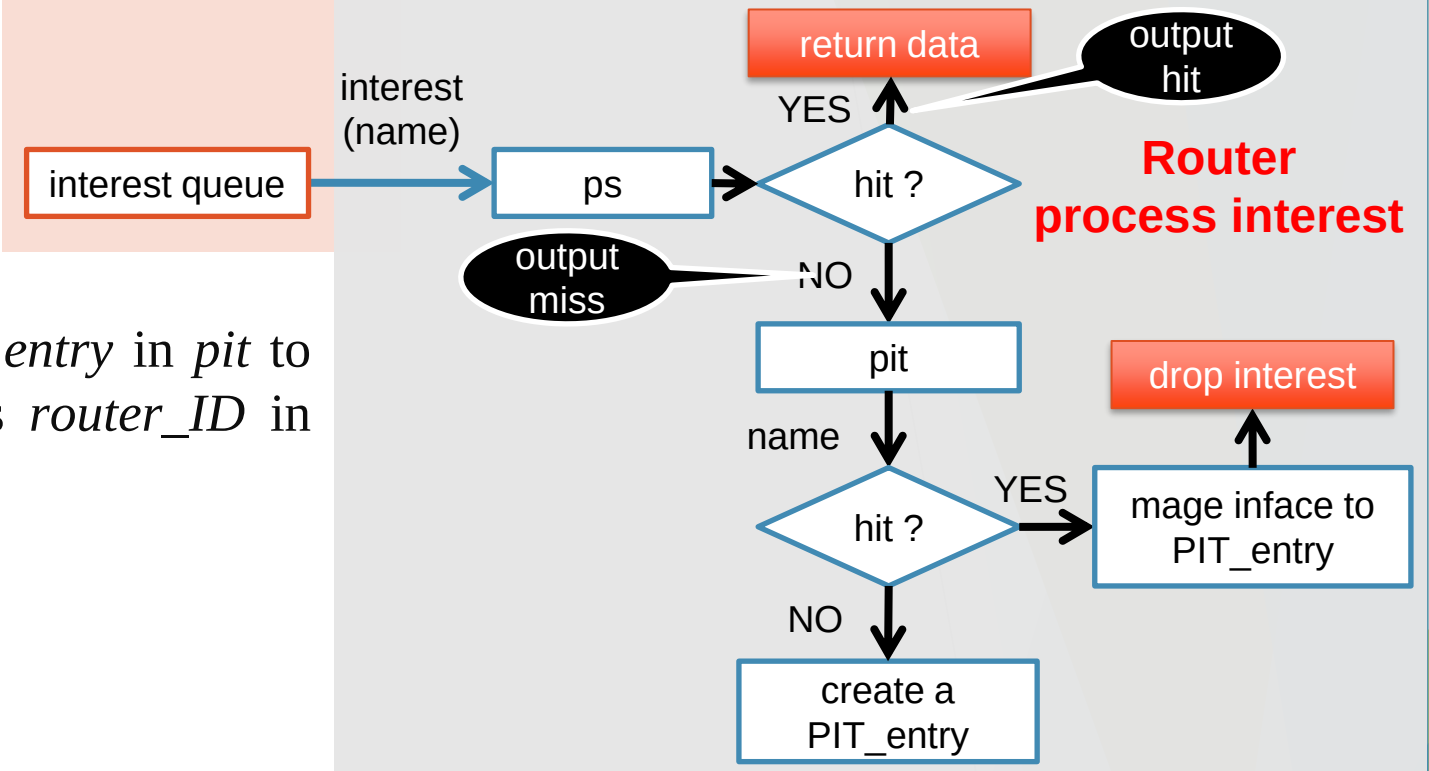
7. Process Flow

- **Interest process**
- If *content name* miss in *pit*, create a new *entry* in *pit* to record the *content name* and *inface* (it is *router_ID* in *interest*).
- ***PIT_entry***

= [[inface], []]

- ***pit***

= {... , 'content_name': [[inface], []]}



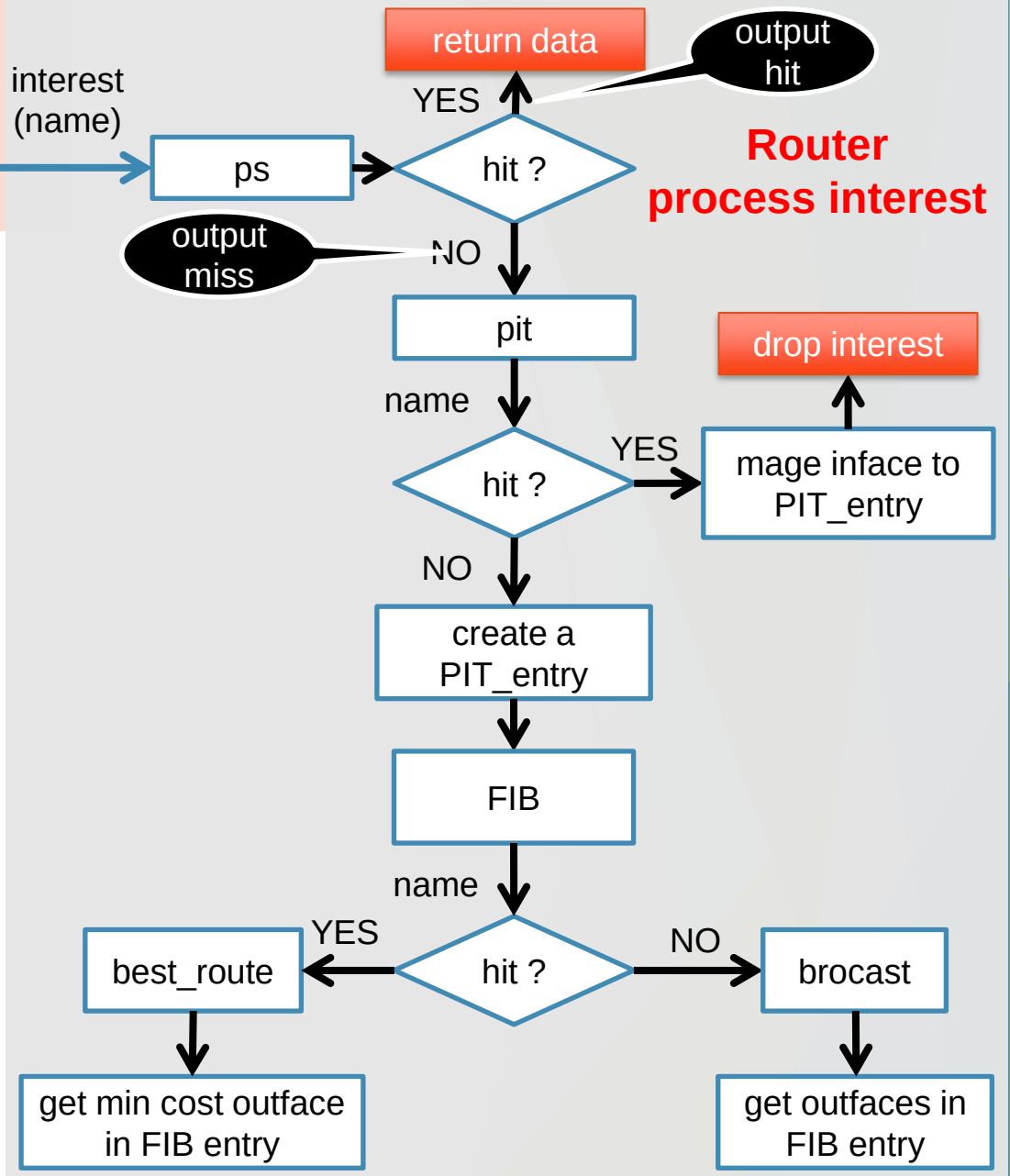
7. Process Flow

- **Interest process**
- Then, go to FIB to find if there is an *entry* that matches the *content name*.
- If NO, broadcast the *interest* to all neighbors.
- Otherwise, choose the *best_route* strategy.That is, from the *outgoing interfaces* of the matched entry, the *outface* with the lowest *cost* is selected to forward the *interest packet*.
- *fib* format

= {'content_name': [[outface, cost, time], ...], ... }

- *fib_entry* format

= [[outface, cost, time], ...]



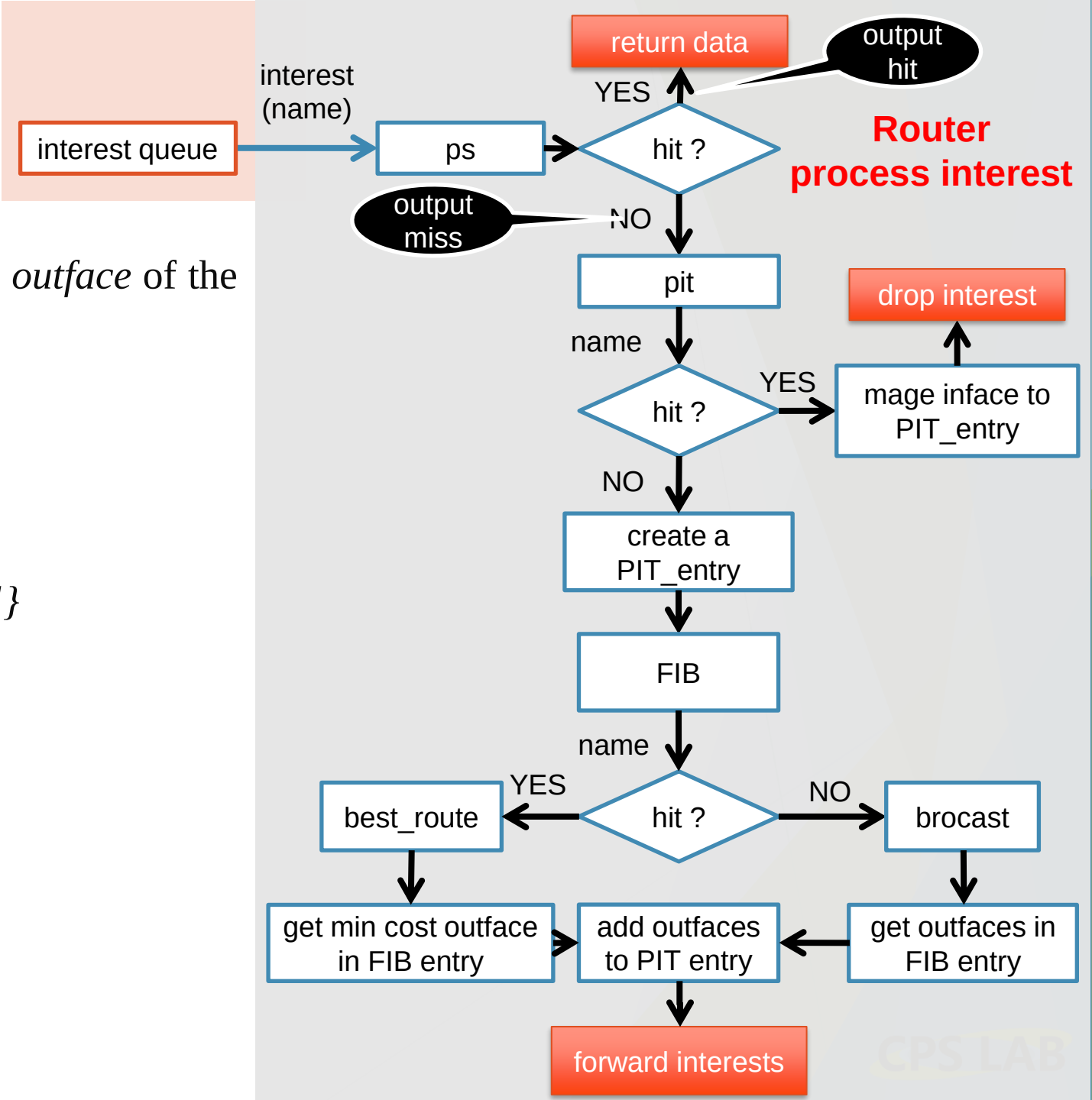
7. Process Flow

- **Interest process**
- And record these *outgoing interfaces* in the *outface* of the matching *entry* in *pit*.
- ***PIT_entry***

= *[[inface], [outface, ...]]*

- ***pit***

= *{... , 'content_name': [[inface], [outface, ...]]}*

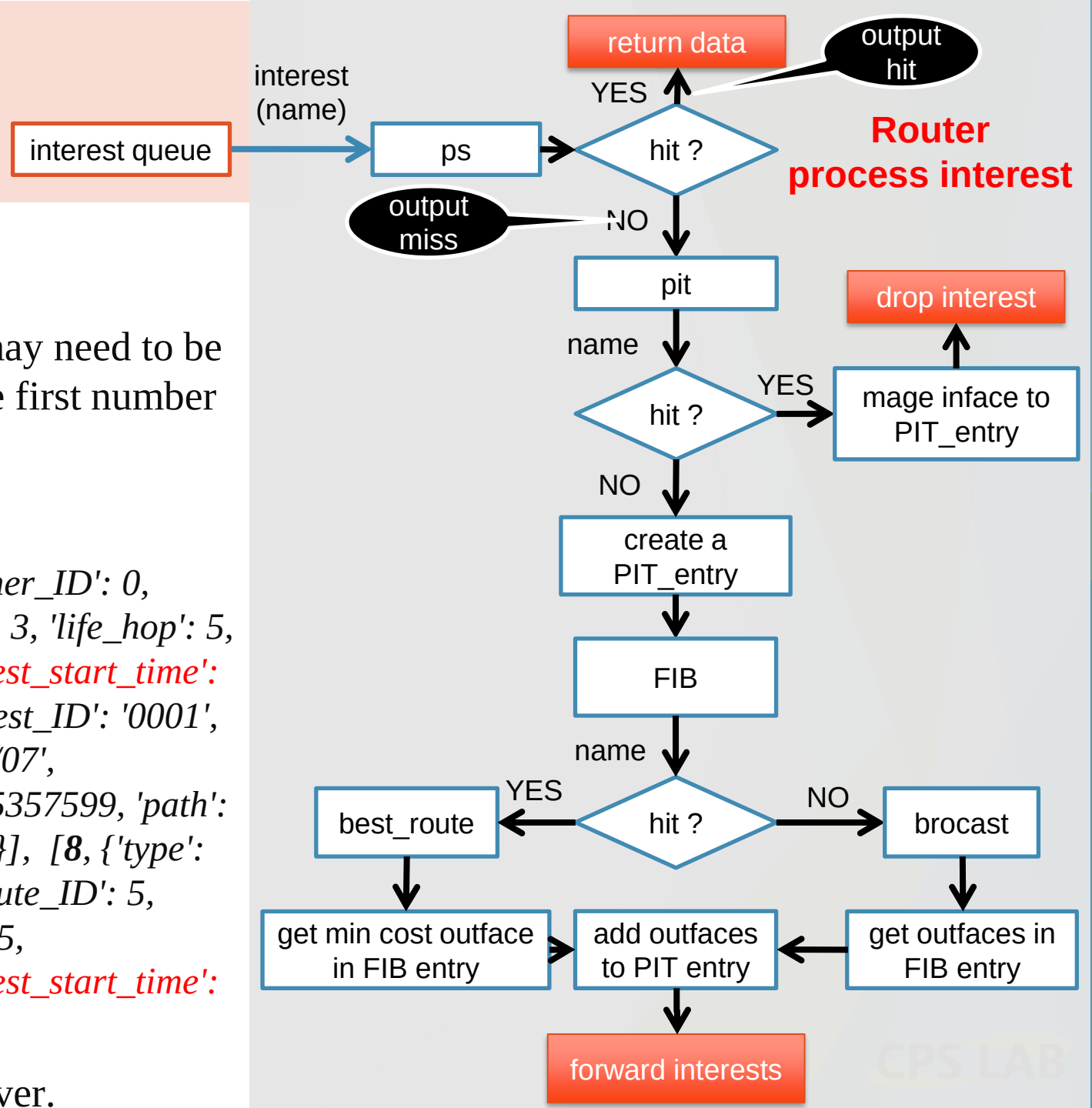


7. Process Flow

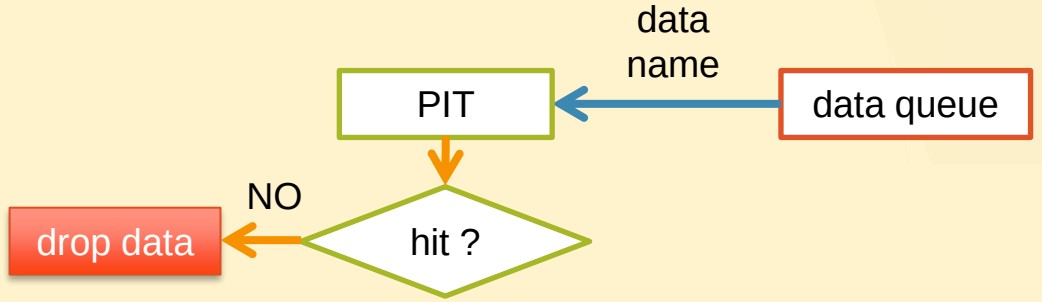
- **Interest process**
- *interest* miss in *ps*
- Create forwarding *interest packets*, which may need to be forwarded to multiple *output interfaces*. The first number of each list is the *outface* (router ID).
- interest packets format

*=[[**7**, {'type': 'interest', 'interest_ID': '0001', 'consumer_ID': 0, 'route_ID': 5, 'content_name': 'r7/07', 'interest_hop': 3, 'life_hop': 5, 'run_start_time': 1615357599, 'path': 'p0/3/5', 'interest_start_time': 0, 'data_start_time': 0}], [**4**, {'type': 'interest', 'interest_ID': '0001', 'consumer_ID': 0, 'route_ID': 5, 'content_name': 'r7/07', 'interest_hop': 3, 'life_hop': 5, 'run_start_time': 1615357599, 'path': 'p0/3/5', 'interest_start_time': 0, 'data_start_time': 0}], [**8**, {'type': 'interest', 'interest_ID': '0001', 'consumer_ID': 0, 'route_ID': 5, 'content_name': 'r7/07', 'interest_hop': 3, 'life_hop': 5, 'run_start_time': 1615357599, 'path': 'p0/3/5', 'interest_start_time': 0, 'data_start_time': 0}]]*

- The *interest packets* is forwarded by the server.



7. Process Flow



Router process data

- **Data process**
- The router takes the first *packet* from the *data_queue* for processing each time.
- The router gets *name* from packet. Go to *pit* to find if there is matching *name*.
- ***pit*** format

= {'content_name': [[inface, ...], [outface, ...]], ... }

- If it miss, *data* is droped. The router takes a *interest packet* from the *interest_queue* for processing.

CPS LAB

7. Process Flow

- **Data process**
- At the same time, check whether the FIB is full. If FIB is smaller than *fib_size*, then update the *content name* and routing information (*outface*) to the FIB.
- *fib* format

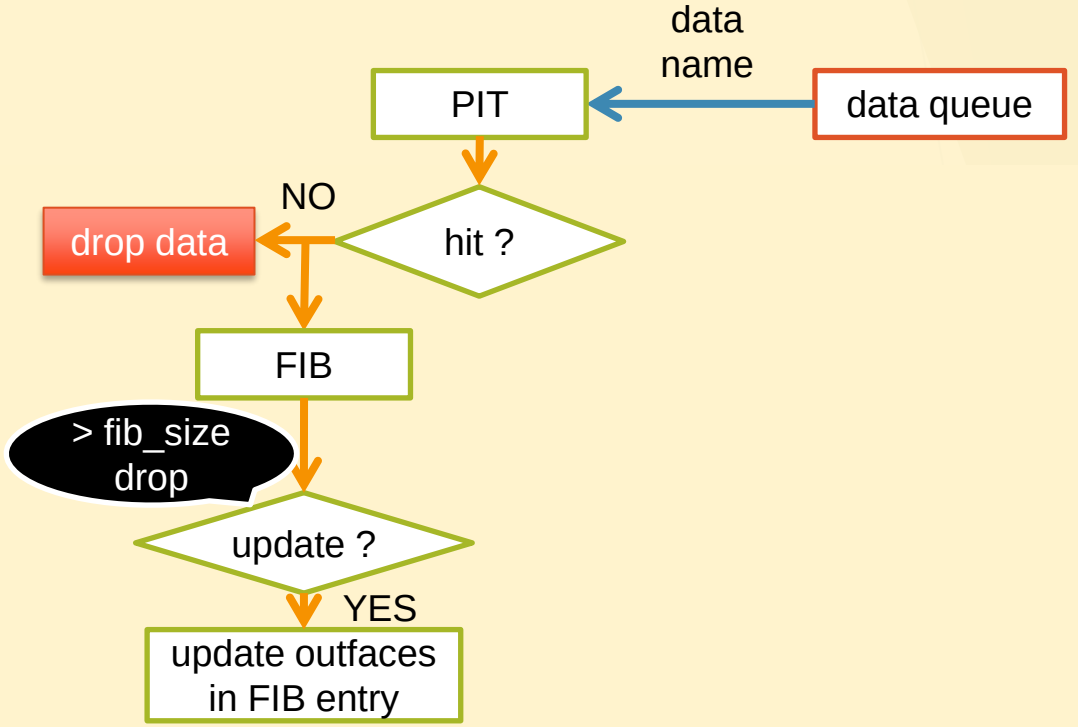
= {'content_name': [[outface, cost, time], ...], ... }

- *fib_entry* format

= [[outface, cost, time], ...]

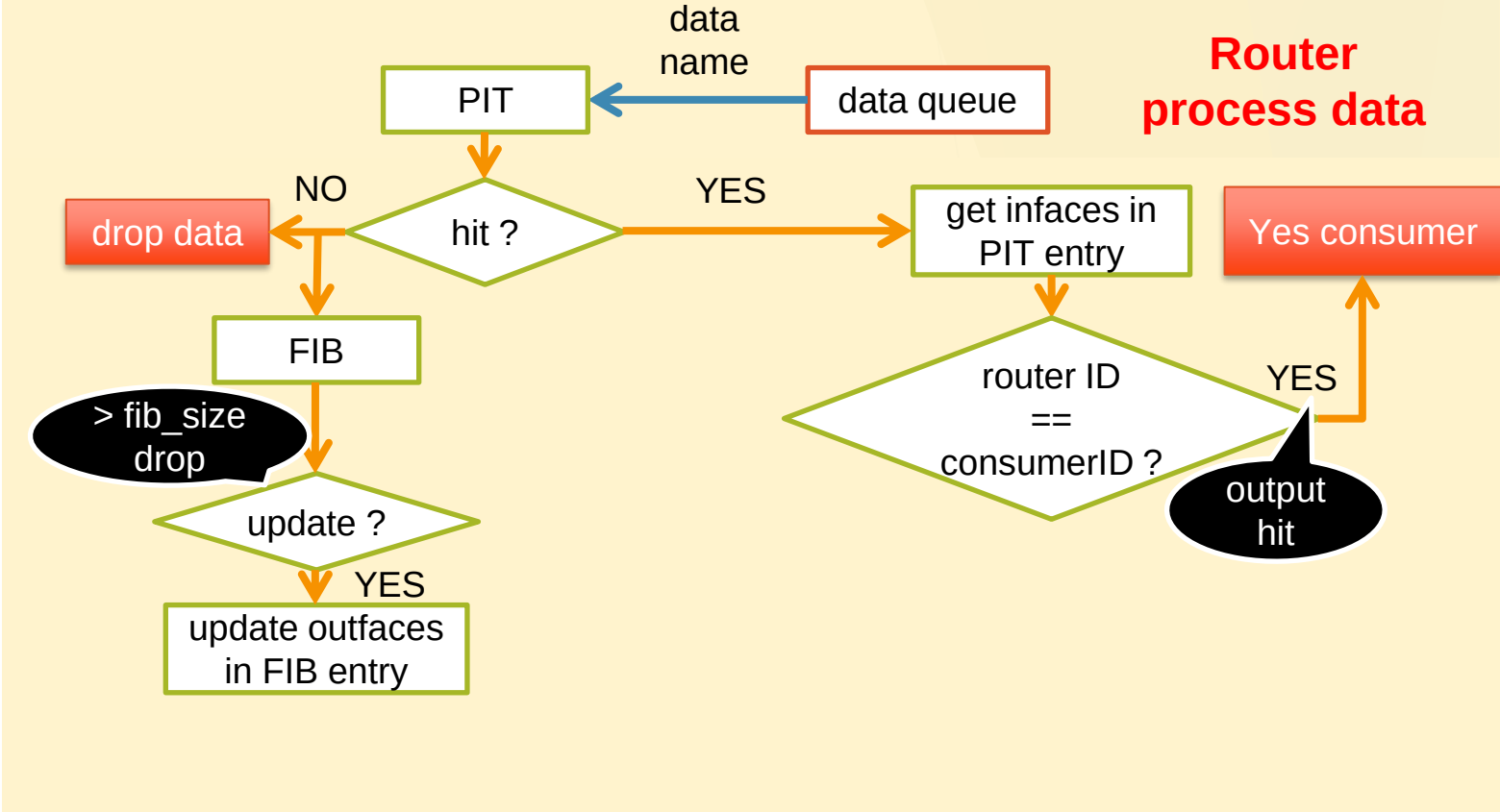
time = 'data_start_time'

cost = current_time - interest_start_time



CPS LAB

7. Process Flow



- **Data process**
- Otherwise, it means that this is the first *data* returned for this *name*. Get the *incoming interfaces* from the *PIT_entry*.
- ***pit*** format

= {'content_name': [[inface, ...], [outface, ...]], ... }

- ***PIT_entry*** format

= [[inface, ...], [outface, ...]]

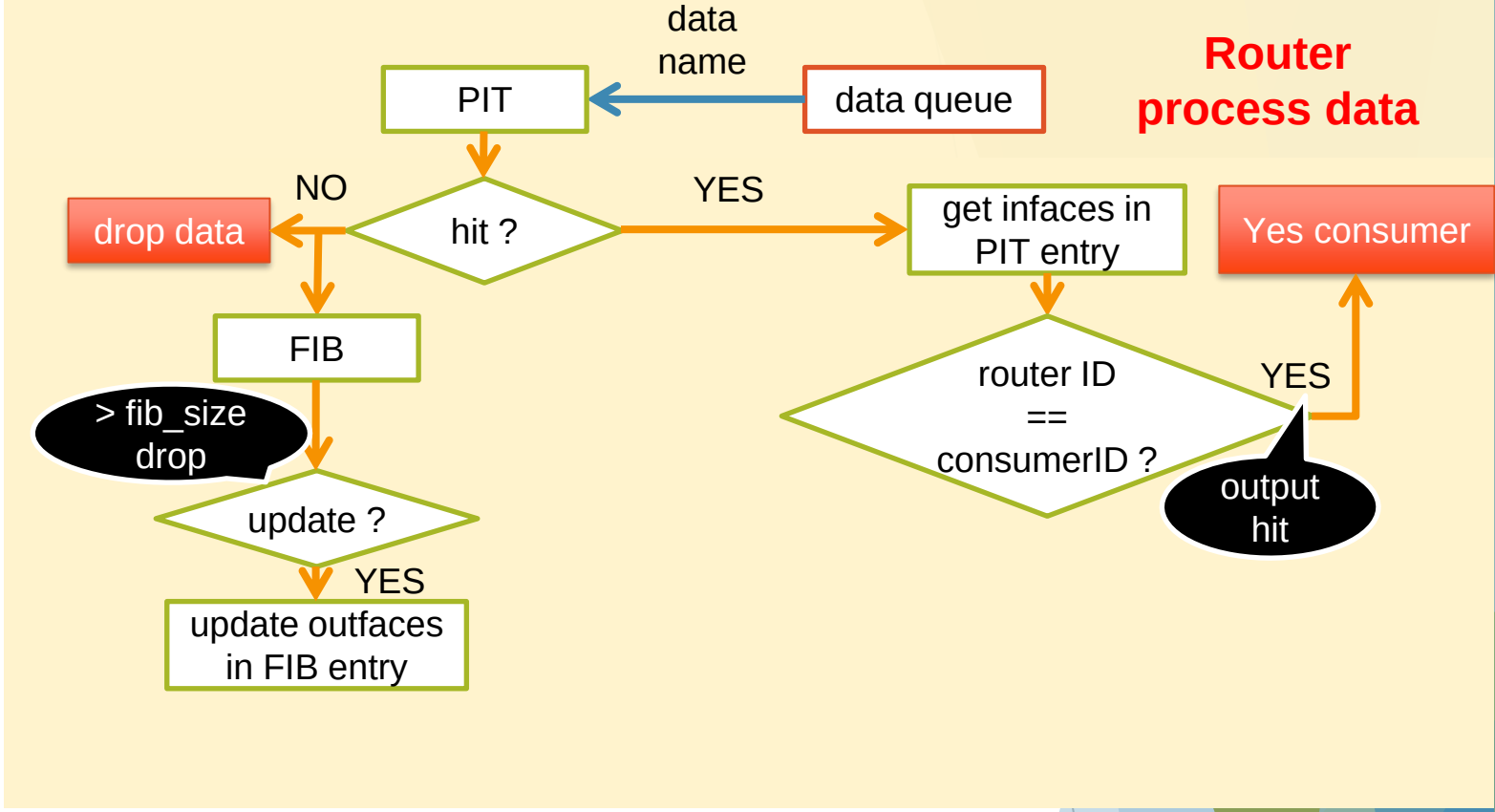
- Determine whether the current *router_ID* is equal to the *consumer_ID* in the *data packet*. If YES, it means that the consumer has received a data response.

CPS LAB

7. Process Flow

- **Data process**
- Data Output.CSV format

=["Time"=str(times-data['run_start_time']),
"Type"=data['type'],
"Consumer_ID"='C'+str(data['consumer_ID']),
"Route_ID"='R'+str(data['route_ID']),
"Content_name"=data['content_name'],
"Data_hop"=data['data_hop'],
"Path"=data['path'],
"Result"='Data hit in consumer',
"Hit_consumer"=1,
"Hit_PIT"=1,
"Hit_Miss"=0,
"response_time"= current_time - interest_start_time]

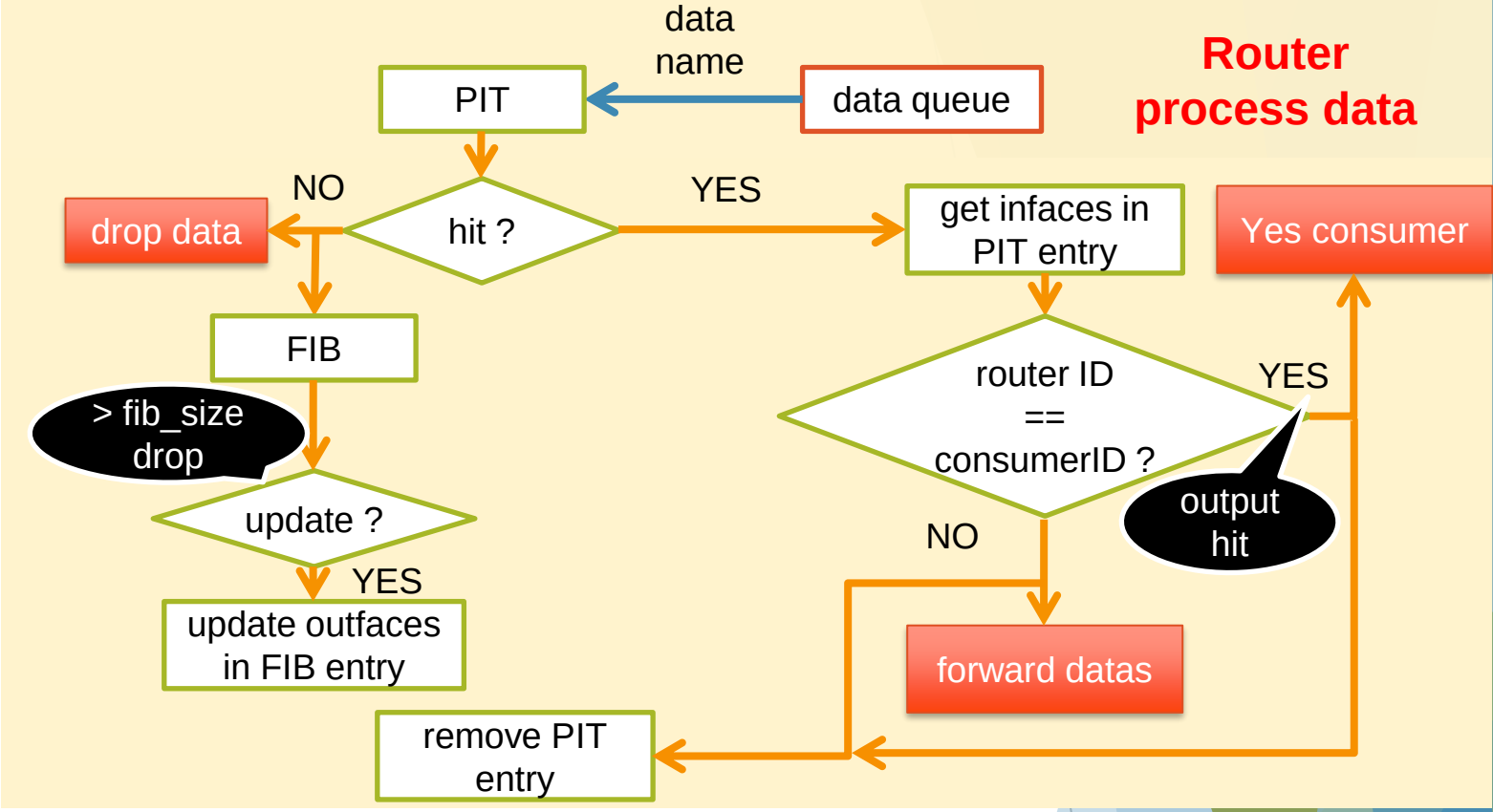


CPS LAB

7. Process Flow

- **Data process**
- Remove this *content_name* record from *pit*.
- Otherwise, forward the *data packet* to all routers on the *incoming interface* and remove this *content_name* record from *pit*.
- ***pit*** format

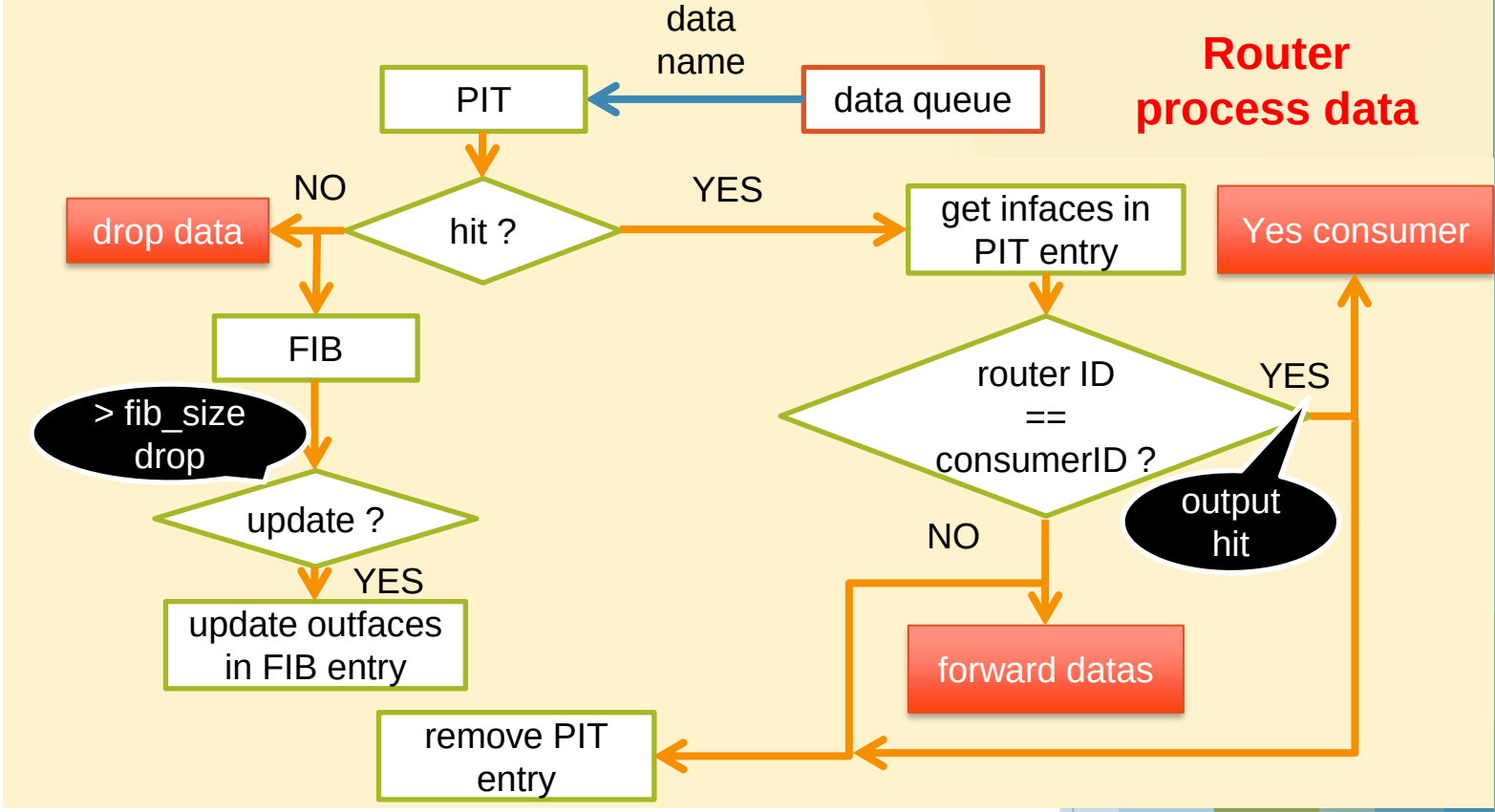
= {'content_name': [[inface, ...], [outface, ...]], ... }



CPS LAB

7. Process Flow

- **Data process**
- *data* hit in *pit*
- Create forwarding *data packets*, which may need to be forwarded to multiple *incoming interfaces*. The first number of each list is the *incoming interface* (next *router ID*).
- *data packets* format



= [[2, {'type': 'data', 'consumer_ID': 0, 'route_ID': 4, 'content_name': 'r5/09', 'content_data': '', 'data_hop': 2, 'run_start_time': 1615357615, 'path': 'p5/4/', 'interest_start_time': 1615357620, 'data_start_time': 1615357634}],

[6, {'type': 'data', 'consumer_ID': 0, 'route_ID': 4, 'content_name': 'r5/09', 'content_data': '', 'data_hop': 2, 'run_start_time': 1615357615, 'path': 'p5/4/', 'interest_start_time': 1615357620, 'data_start_time': 1615357634}]]

- The *data packets* is forwarded by the server.

CPS LAB

7. Process Flow

- **Data process**
- At the same time, check whether the CS is full. If CS is smaller than *cs_size*, then cache the *content data* to the CS.
- The cache size of CS is limited. When the CS is full, you need to optimize how to update records. (FIFO, LRU, LFU, Cost-based or Time-based etc.)
- cs format

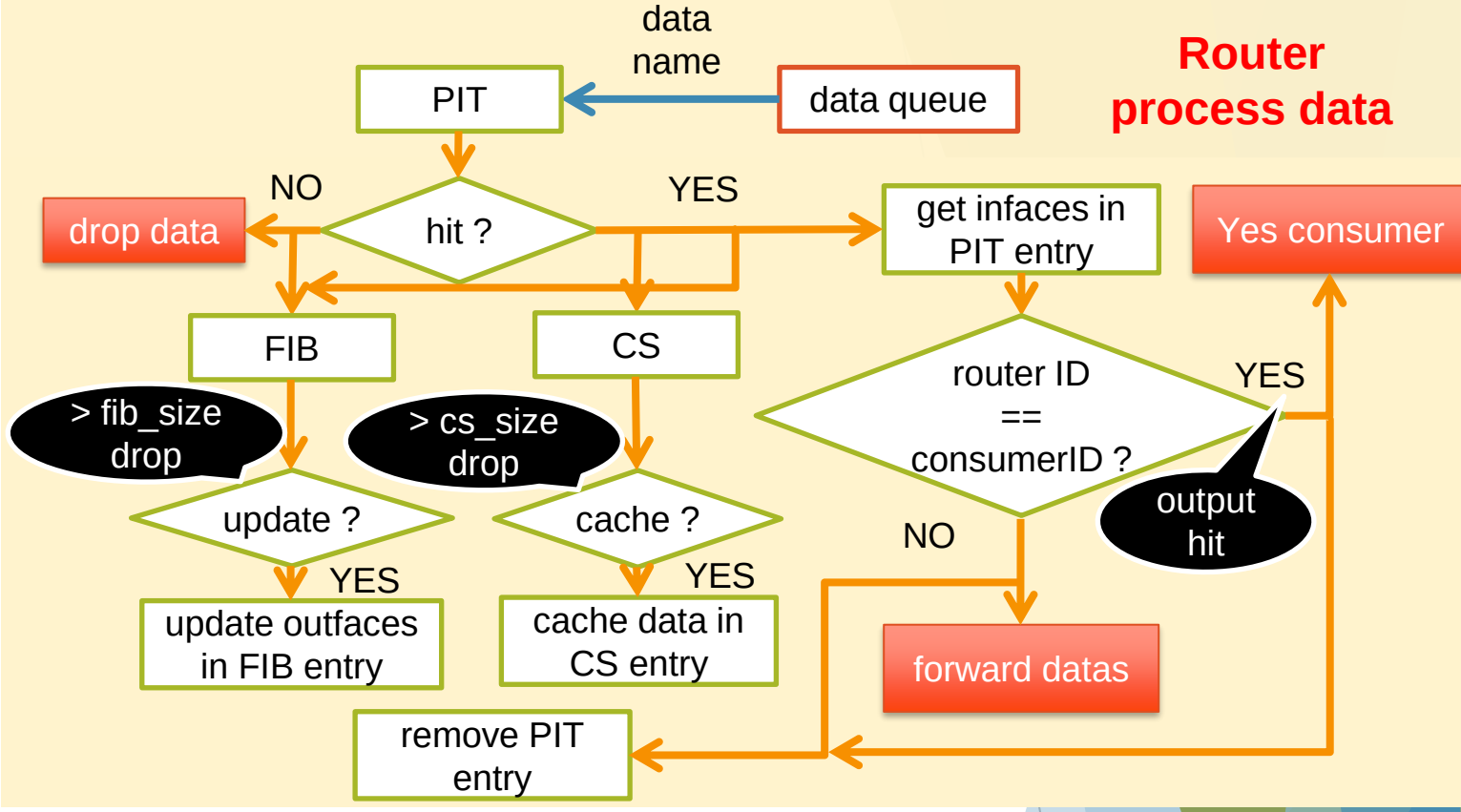
= [[content_name, data, time, cost], ...]

- *cs_entry* format

= [content_name, data, time, cost]

time = 'data_start_time'

cost = current time - interest start time



CPS LAB

8. Coding----main.py

```
# Read network
def load_network():

# Read parameters
def load_peremiters():

# Read the contents produced by each producer
def input_producer_contents():

# Read the interest packets to be sent by each router
def input_interests():

def main():
```

Network is a dict.
key = router name ex. 'r0'
value = [router ID, ...] ex. [1, 3]

Peremiters is a dict.
key = Peremiter name ex.'route_num'
value = Peremiter value ex. 12

Producer contents is a dict.
key = Producer ID ex. 'p1'
value = [Content name, ...] ex. ['r1/0', 'r1/99']

Interests is a dict.
key = router ID ex. 'r1'
value = [{'interest ID': , 'Content name': }, ...] ex. [{'interest ID': 0001, 'Content name': 'r1/99'}]

Initialization parameters
Get the time when the simulator started running *run_start_time*
Build a server for each router
At regular intervals（frequency） in the while loop, all routers send out new interest packets to the network. At the same time, it keeps checking whether the simulator end time is up.

8. Coding----server.py

```
class Server(threading.Thread):
    def __init__(self, serverID, sizes, producer_contents, run_start_time, network, HOST='127.0.0.1'):

    # Create thread
    def run(self):

    # Each router sends a fixed number of new interest packets to the network every second
    def start_network(self, run_start_time, frequency, content_num, route_num, interests):

    # Receive packet
    def accept(self):

    # process interest
    def interest_process(self):

    # process data
    def data_process(self):
```

create a accept thread
create a interest_process thread
create a data_process thread

The router sends a new interest packet to the network.

Monitor whether a packet is received. If packet is received, read the packet type to determine whether it is interest or data packet. Then store the packet in the corresponding queue. At this time, to determine whether queue is full. If it is full, drop this packet, otherwise save it.

The router takes the first interest packet from *interest_queue* for processing

The router takes the first data packet from *data_queue* for processing

CPS LAB

8. Coding----network.py

```
class NETWORK():
    def __init__(self):

    # Create a network topology
    def Creat_network(self, network):

    # Get a network topology
    def Get_network(self):
```

Create a *network* dictionary.

Create a *network* dictionary, assign the *network* dictionary read from the networks JSON file to it, and return this dictionary.

return *network* dictionary.

CPS LAB

8. Coding----ps.py

```
class PS():
    def __init__(self):

    # Producer generates unique content name
    def Creat_ps(self, route_ID, route_num, content_num, producer_content):

    def Get_ps(self):

    # Check if there is data matching the content name in ps
    def Search_ps_interest(self, ps, content_name):
```

Create an empty *ps* list.

Store the producer contents of the current router read from the producer content JSON file into *ps* list of router.

return *ps* list of router.

get the *content name* from the *interest* packet, and look for matching *data* in *ps*. If it matches, return TRUE, otherwise return FALSE.

CPS LAB

8. Coding----pit.py

```
class PIT():
    def __init__(self):

    # Each router creates an independent PIT table
    def Creat_pit(self, route_ID):

    def Get_pit(self):

    # Get the entry of the content name from the pit
    def Get_pit_entry(self, content_name):

    # The outface is updated to pit
    def Update_pit_outface(self, pit, Outfaces, interest):

    # The inface of the received interest packet is merged into the same content name
    def Merge_pit_entry(self, interest):
```

Create an empty *pit* dictionary.

return an *pit* dictionary.

return an *pit* dictionary.

Get the value (*PIT_entry* list) from the *pit* dictionary with the *content name* as the key and return it.

Get the value (*PIT_entry* list) from the *pit* dictionary with the *content name* as the key. Add the *outfaces* to the outface of the *PIT_entry* list.

Get the value (*PIT_entry* list) from the *pit* dictionary with the *content name* as the key. Merge the *inface* (*route_ID* of *interest*) to the inface of the *PIT_entry* list. At the same time, make sure that the *inface* is not repeated in inface of the *PIT_entry* list.

CPS LAB

8. Coding----pit.py

```
# Create a pit entry
def Creat_pit_entry(self, interest):

# Check whether there is an entry matching the content name of the interest packet in the pit
def Search_pit_interest(self, pit, interest):

# Check whether there is an entry matching the content name of the data packet in the pit
def Search_pit_data(self, pit, data):

# The content_name entry is removed from pit
def Remove_pit_entry(self, pit, data):
```

Create a *PIT_entry* in the *pit* dictionary with the *content name*. Add the *inface* (*route_ID* of *interest*) to the inface of the *PIT_entry*.

Get *content name* from the *interest*. Check matching *PIT_entry* in *pit*. If it matches, merge *incoming interface* (*route_ID* of *interest*) into inface of *PIT_entry* and return FALSE. Otherwise create a new *PIT_entry* in *pit* and return TRUE.

Get the *content name* from the *data* packet. Check matching *PIT_entry* in *pit*. If it matches, return TRUE. Otherwise return FALSE.

Get the *content name* from the *data* packet. Check matching *PIT_entry* in *pit*. If it matches, return TRUE. Otherwise return FALSE.

CPS LAB

8. Coding----interest.py

```
class INTEREST():
    def __init__(self):

    # Consumer generated interest packet
    def Generate_interest(self, route_ID, run_start_time, frequency, content_num, route_num, interest):

    # Check whether the interest packet has timed out
    def Time_out(self, interest):

    # Pack the interest packet to be sent and the output interface
    def Send_interest(self, pit, Outfaces, route_ID, interest):
```

Create a *interest* dictionary.

Get N new *interest packets* belonging to this router from the interest JSON file. And reconstruct it according to the complete interest packet format. Note that the *life_hop* is set to 5. Pack them in a list and return.

Determine whether the *interest_hop* of the *interest* is greater than the *life_hop*. If yes, return an error and drop the *interest* , without recording it in the *interest_queue*.

Pack *interests* to be forwarded into a list according to the *outfaces*. The *interest_hop* is added by 1, and the *path* of interest is added to the current *router ID*. At the same time, the *outfaces* is updated to the *PIT_entry* matching *content_name*.

CPS LAB

8. Coding----interest.py

```
# Interest packet processing
def On_interest(self, route_ID, interest, tables):

# output information of the interest packet
def Output_interest_txt(self, interest, times, result, hit, miss):

def Drop_interest(self, route_ID, interest):
```

Get *content name* from the *interest* packet. Check if there is matching *data* in *ps*. If there is a match, create a *data packet*. Then output the information that the **"interest hits in ps"** to CSV and return the data packet.
Otherwise, output the information that the **“interest miss in ps”** to interest.CSV.

Output *interest packet* information and write to interest.CSV

Output the information of *interest packet* and write it to interest.CSV

CPS LAB

8. Coding----data.py

```
class DATA():
    def __init__(self):

    # Create a data packet
    def Create_data(self, route_ID, interest):

    # Pack the data packet to be sent and the output interface
    def Send_data(self, Infaces, route_ID, data):

    # data packet processing
    def On_data(self, sizes, route_ID, data, tables):
```

Create a *data packet* dictionary.

Create a *data packet* according to the complete *data packet* format. The content data is a random number ranging from 0 to 100,000.

Pack *datas* to be forwarded into a list according to the *infaces*. The *data_hop* is added by 1, and the *path* of data is added to the current *router ID*.

Get *content name* from the *data packet*. Check if there is matching *data* in *pit*. If there is a match, then check whether the router ID is the same as the consumer ID. If yes, output the information that the **"*data hit in consumer*"** to data.CSV. Otherwise, output the information that the **"data hit in pit"** to data.CSV and forward *data packet*.
If not match in pit, output the information that the **"data miss in pit"** to data.CSV.

CPS LAB

8. Coding----data.py

```
def Drop_data(self, inface, data):

# output information of the data packet
def Output_data_txt(self, data, times, result, hit_consumer, hit_PIT, miss_PIT):
```

Output the drop information of *data packet* and write it to data.CSV

Output the information of *data packet* and write it to data.CSV

CPS LAB

8. Coding----forward.py

```python
class FORWARD():
    def __init__(self):

    # Get data packet forwarding interface
    def Forward_data(self, pit, data):

    # Get interest packet forwarding interface
    def Forward_interest(self, fib, network, route_ID, interest):
```

Get the *inface* (*router ID*) from the *data packet*. Get the *PIT_entry* matching the *content name* from the *pit*. Then pack the infaces of the *PIT_entry* except for the same as the *inface* into the *Infaces*, and return it.
Prevent *data packet* from being transmitted back to the previous router.

Get the *inface* (*router ID*) from the *inteseat packet*. Get the *FIB_entry* matching the *router ID* from the *network*. Then pack the outfaces of the *FIB_entry* except for the same as the *inface* into the *Outfaces*, and return it.
Prevent *interest packet* from being transmitted back to the previous router.

CPS LAB

8. Coding----cs.py

```
class CS():
    def __init__(self):

    # Each router creates an independent cache space
    def Creat_cs(self, route_ID):

    # Get cs
    def Get_cs(self):

    # Check if there is data matching the content name in cs
    def Search_cs_interest(self, cs, content_name):

    # Add an entry to CS
    def Creat_cs_entry(self, data):

    # Delete an entry from CS
    def Remove_cs_entry(self, cs):

    # Cache data
    def Cache_cs_data(self, cs, cache_size, data):
```

Create a CS list

Return a CS list

Return a CS list

Go through each entry in CS and check if there is a matching content name. If it is matched, return Ture. Otherwise, return False.

Get the content name and data, and data_start_time, data_hop from the data packet. Create a new CS entry, record them in this entry.

Sort CS by cost or time. Delete the most cost or earliest recorded entry.

Determine whether the CS size > cache_size. If not, then create a cs entry to cache content data. Otherwise, delete an entry from CS, and then create a new entry to cache content data.

CPS LAB

8. Coding----fib.py

```
class FIB():
    def __init__(self):

    def Creat_FIB(self, route_ID):

    def Get_fib_entry(self, content_name):

    def Add_fib_outface(self, data):

    # Remove the content name with the most cost
    def Remove_fib_entry(self):

    def Add_fib_entry(self, data):
```

Create a fib dictionary and a list of fib_entry.

Return a fib dictionary.

Return a fib entry that matches the content name.

Get the outface, data_start_time and data_hop from the data packet. Check whether FIB is full. If not, update content name and routing information to FIB entry, and re-sort FIB, putting the lowest cost first. Otherwise, remove an outface from FIB entry, and update content name and routing information to FIB entry.

Remove the most costly content name or the longest time content name from FIB.

Add content name and outface to FIB dictionary.

CPS LAB

8. Coding----fib.py

```
# The outface is updated to fib
def Update_fib_outface(self, fib, route_ID, fib_size, data):

# Forward interest packets to all neighbors
def Brocast(self):

# Choose the outface with the min cost to forward the interest packet
def Best_route(self):

# Find in FIB whether there is a matching interest packet entry
def Search_fib_interest(self, fib, route_ID, interest):
```

Get fib entry from FIB based content name, if there is an entry that matches content name. Check whether FIB is full. If it is full, remove an entry from FIB, and then add a new entry to record content name.

Get the neighbor router outface connected to this router, except the router that received theinterest packet.

Get the lowest cost outface from FIB entry.

Check whether there is an entry in FIB that matches the content name of interest packet. If not, then select the broadcast strategy to forward the interest packet. Otherwise, the outface with the lowest cost is selected from the matched entry to forward the interest packet.

CPS LAB

Thank You !

Q&A

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