

HTTP/2 Stream Priority in ATS

ATS Spring 2016 Summit
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Agenda

1. Summary of Stream Priority Specs
2. Algorithms and Implementations
3. Performance
4. Issues / Questions / Discussions

1. Summary of Stream Priority Spec

HTTP/2 Streams are Multiplexed

A single HTTP/2 connection can contain multiple streams.

Client

Server

HEADERS #3

HEADERS #5

HEADERS #3

HEADERS #5

DATA #3

DATA #5

DATA #3

DATA #5

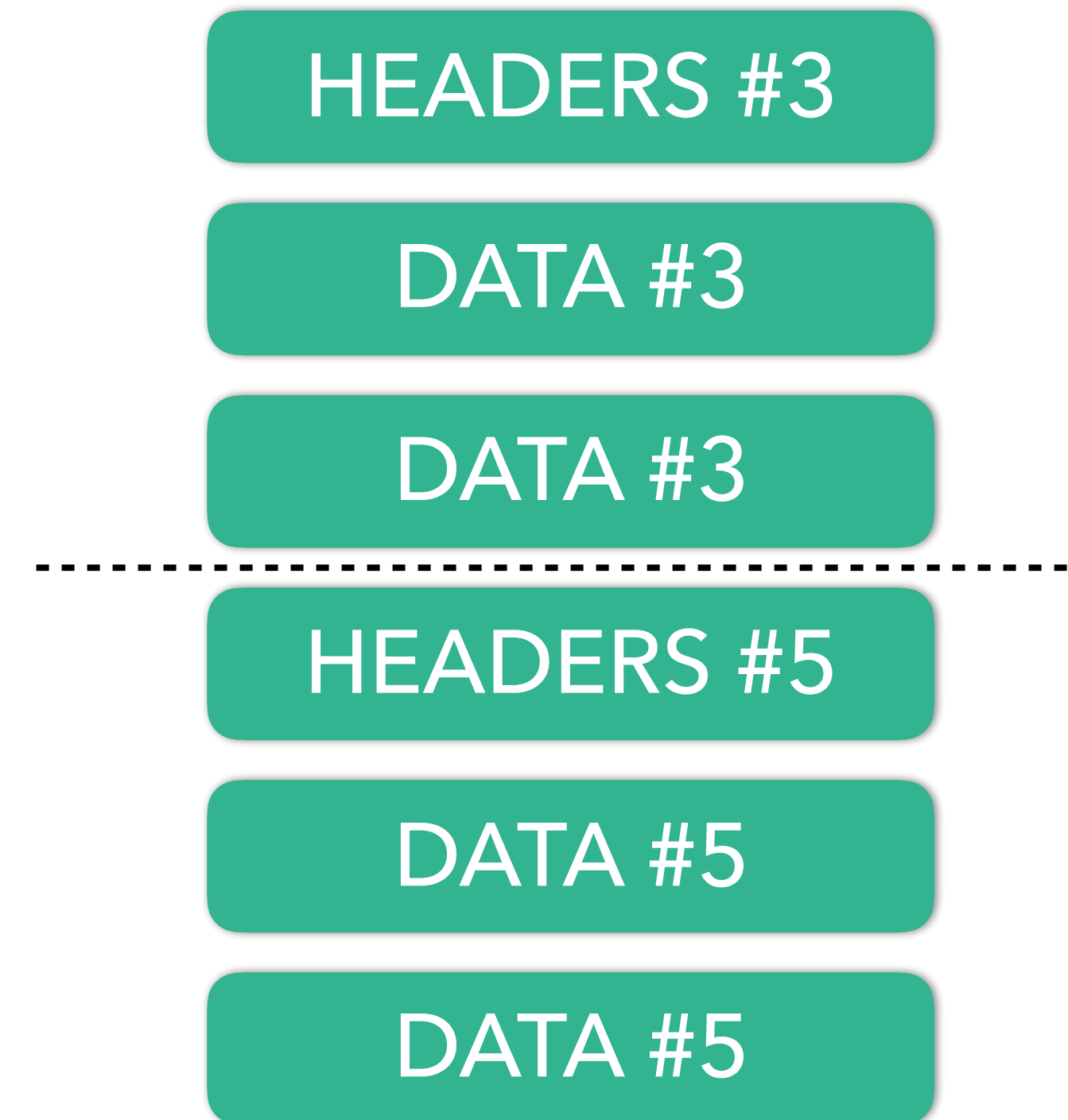
Which stream should be proceed first?

Stream Priority

DependencyTree



Response



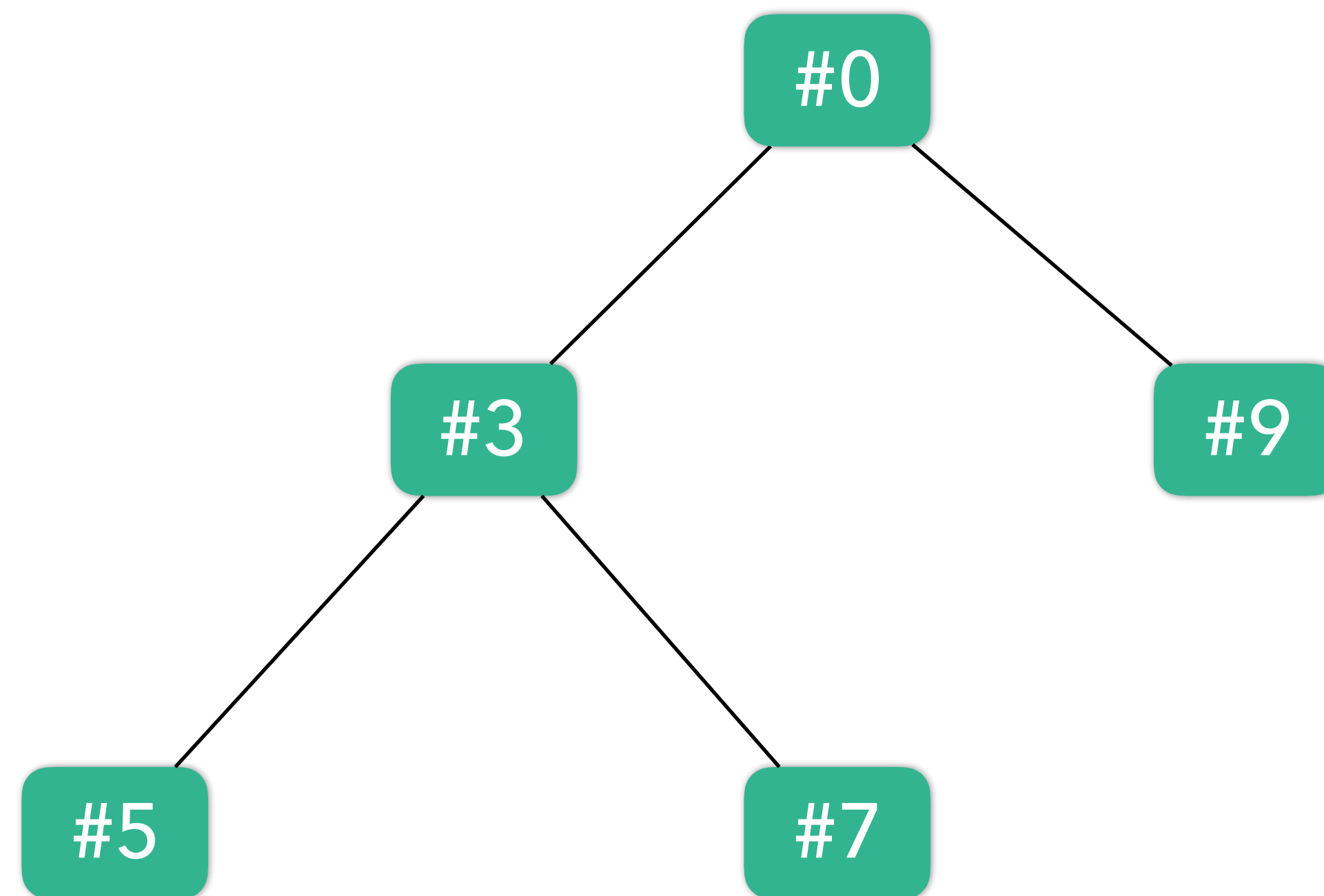
Stream Priority Specs

- Sender (client) can “advise” Stream Priority by sending HEADERS or PRIORITY frame.
- The payload contains
 - Stream Dependency
 - Exclusive Flag
 - Weight

Stream Priority Specs - Stream Dependency

- Each stream can depend on another stream.
- In default, stream depends on stream #0.

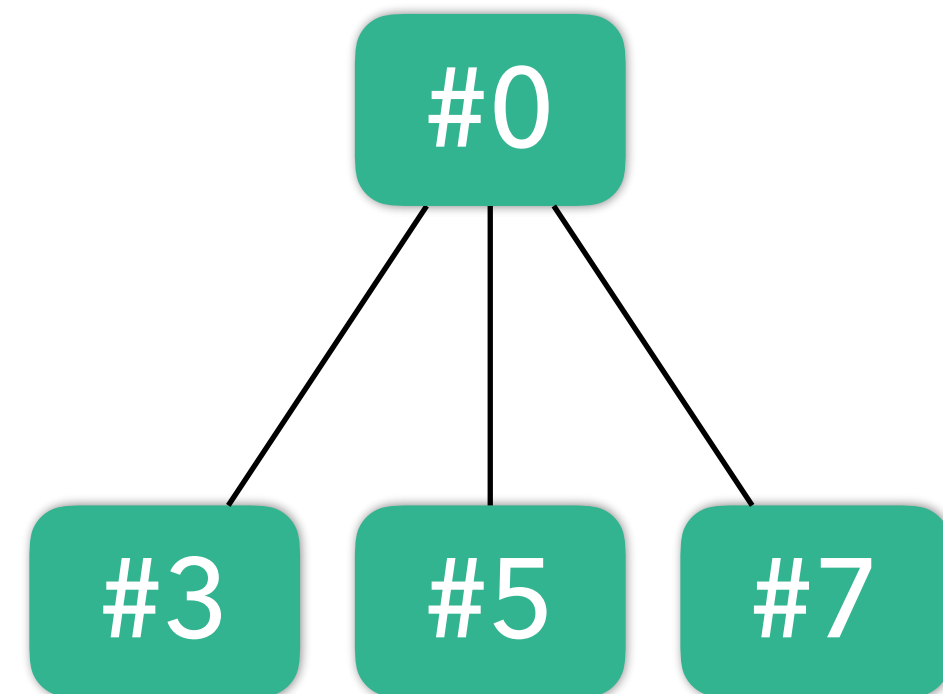
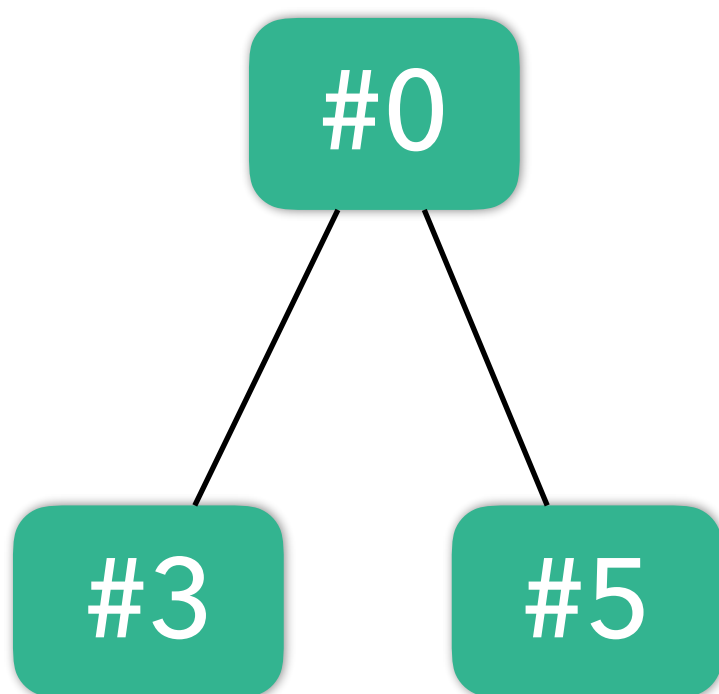
ex:



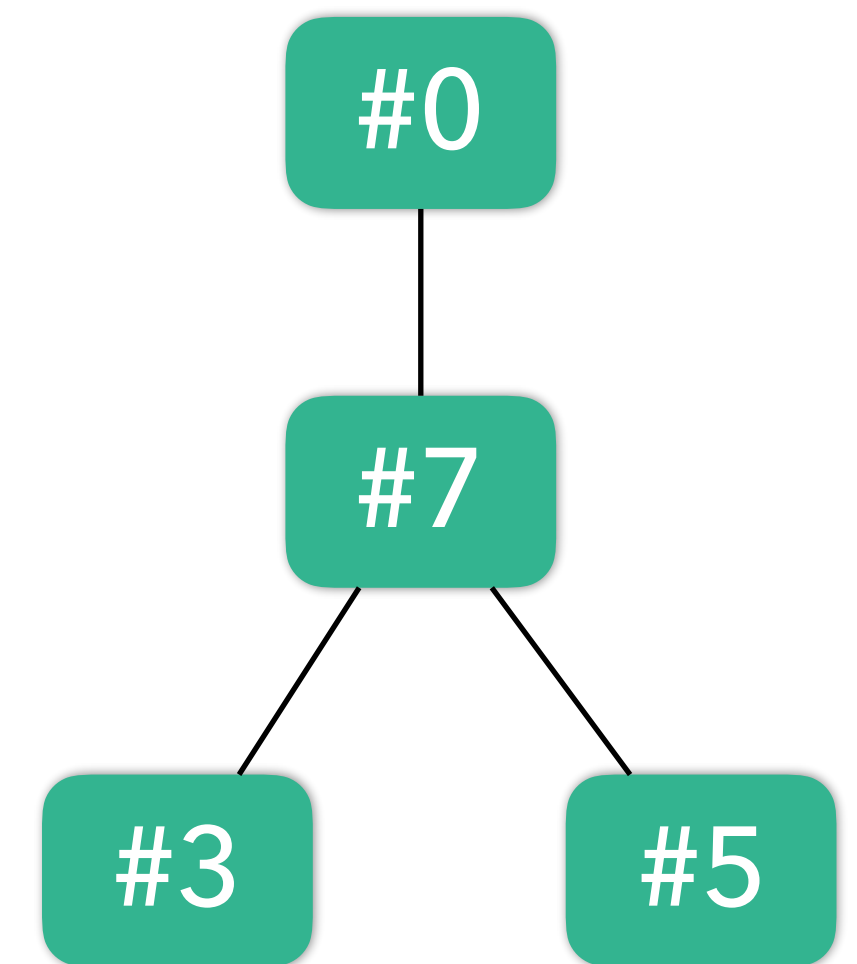
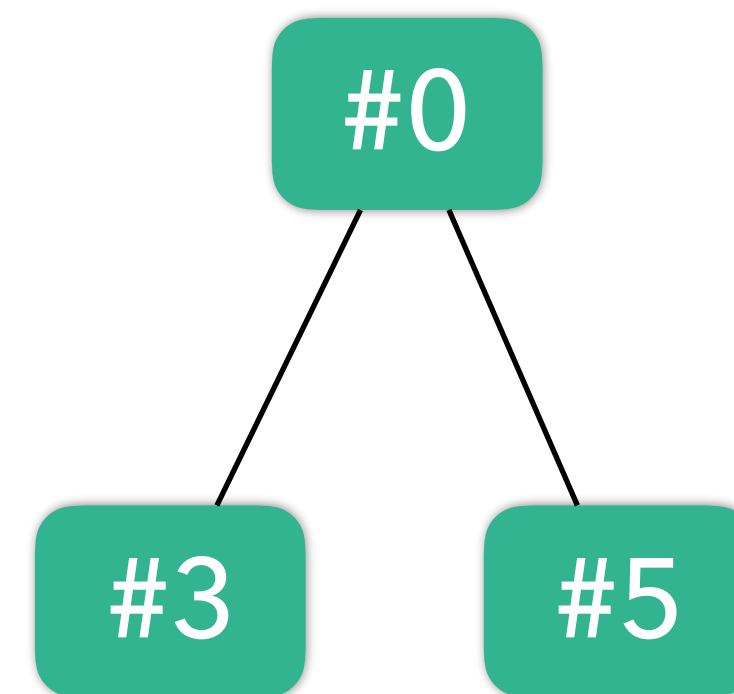
Stream Priority Specs - Exclusive Flag

An exclusive flag allows for the insertion of a new level of dependencies.

Add new stream #7 to the tree



exclusive flag : off

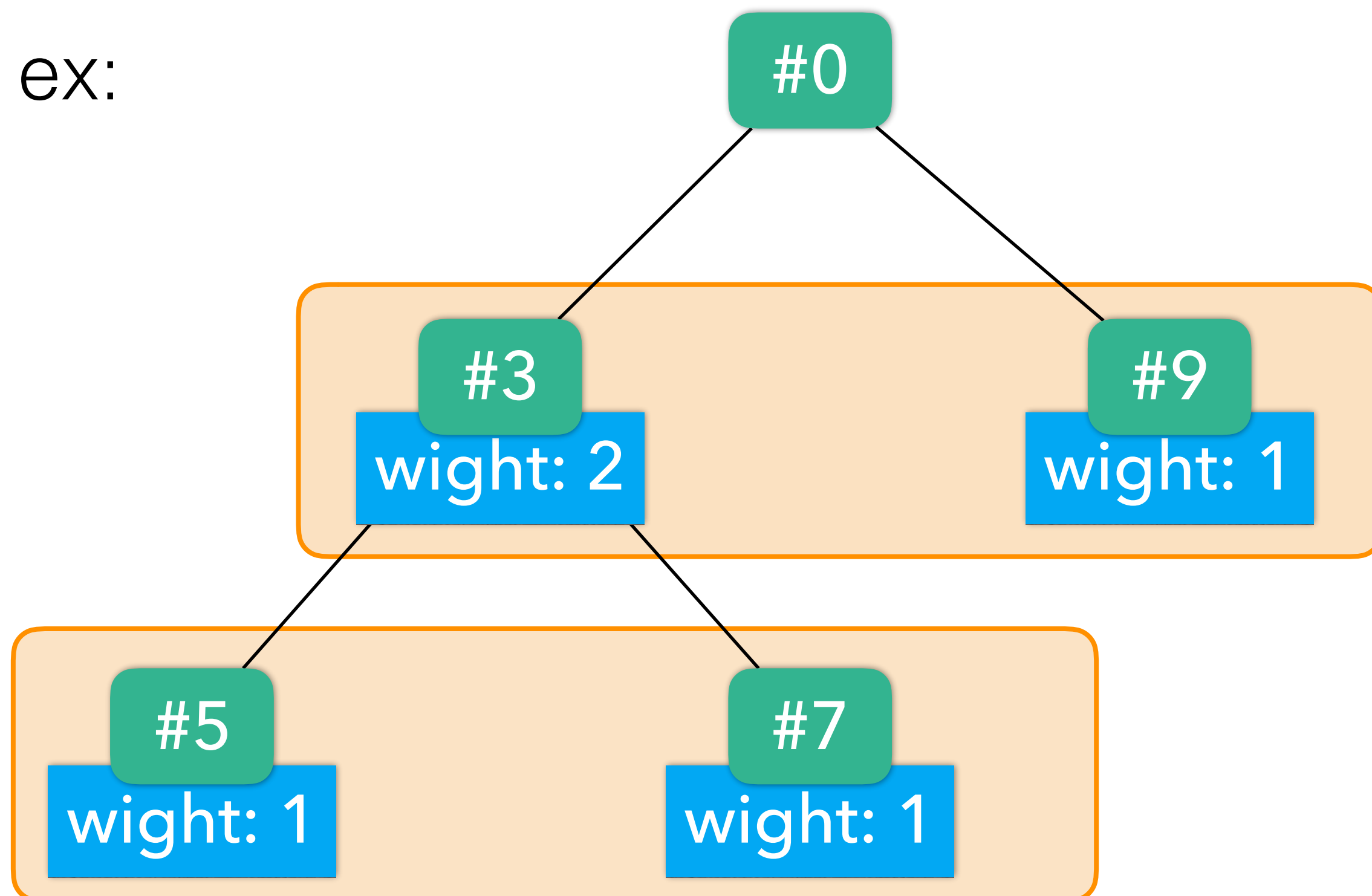


exclusive flag : on

Stream Priority Specs - Weight

- Streams with the same parent SHOULD be allocated resources proportionally based on their weight.

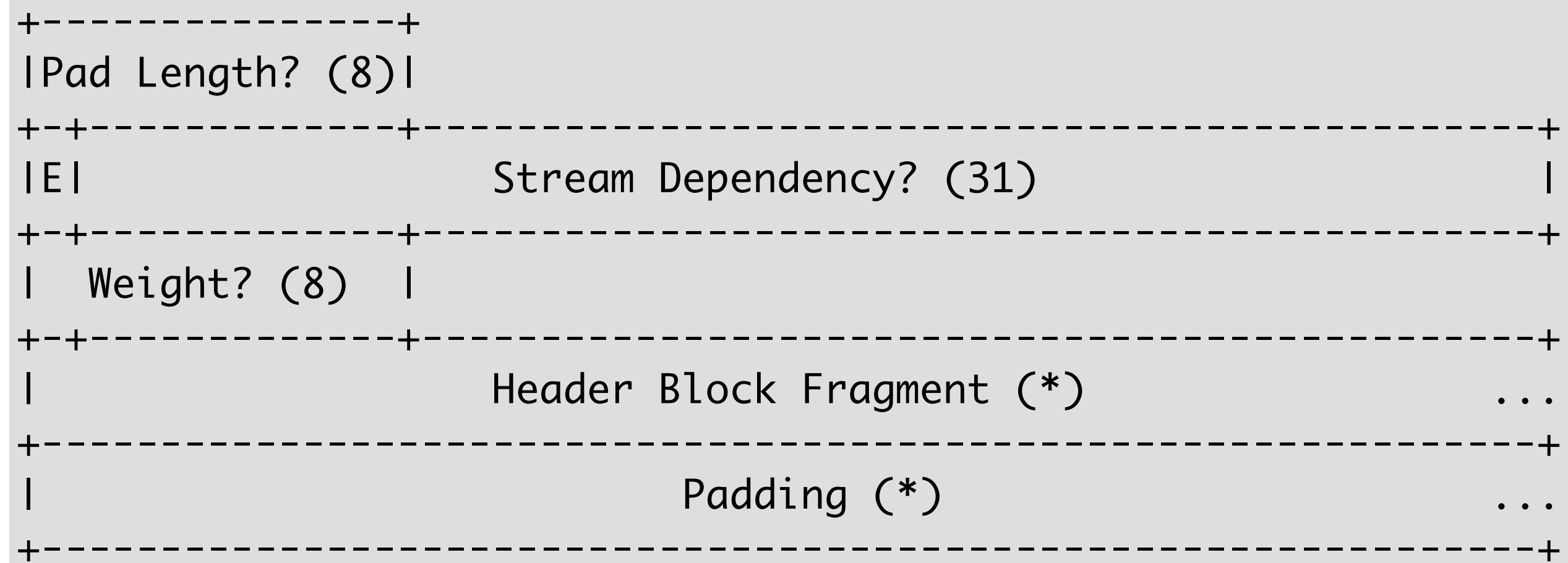
ex:



Response Data Frame Queue



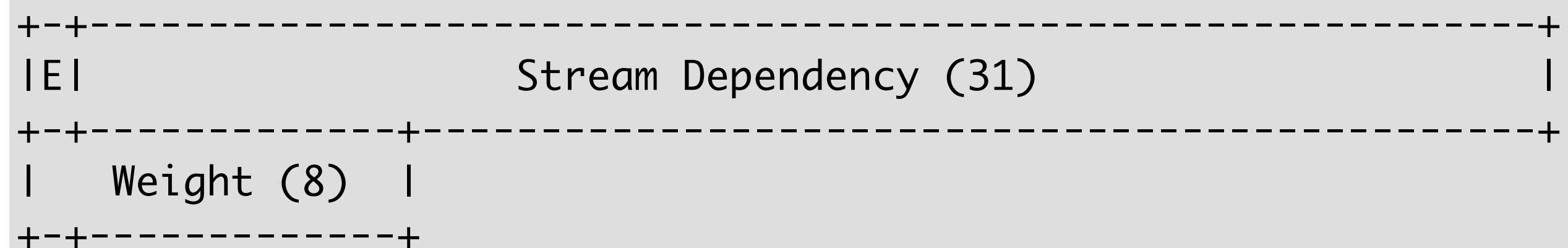
HEADERS Frame



If the PRIORITY flag is set, HEADERS frame contains E, Stream Dependency, Weight fields.

HEADERS frames can be sent on a stream in the "idle", "reserved (local)", "open", or "half-closed (remote)" state.

PRIORITY Frame

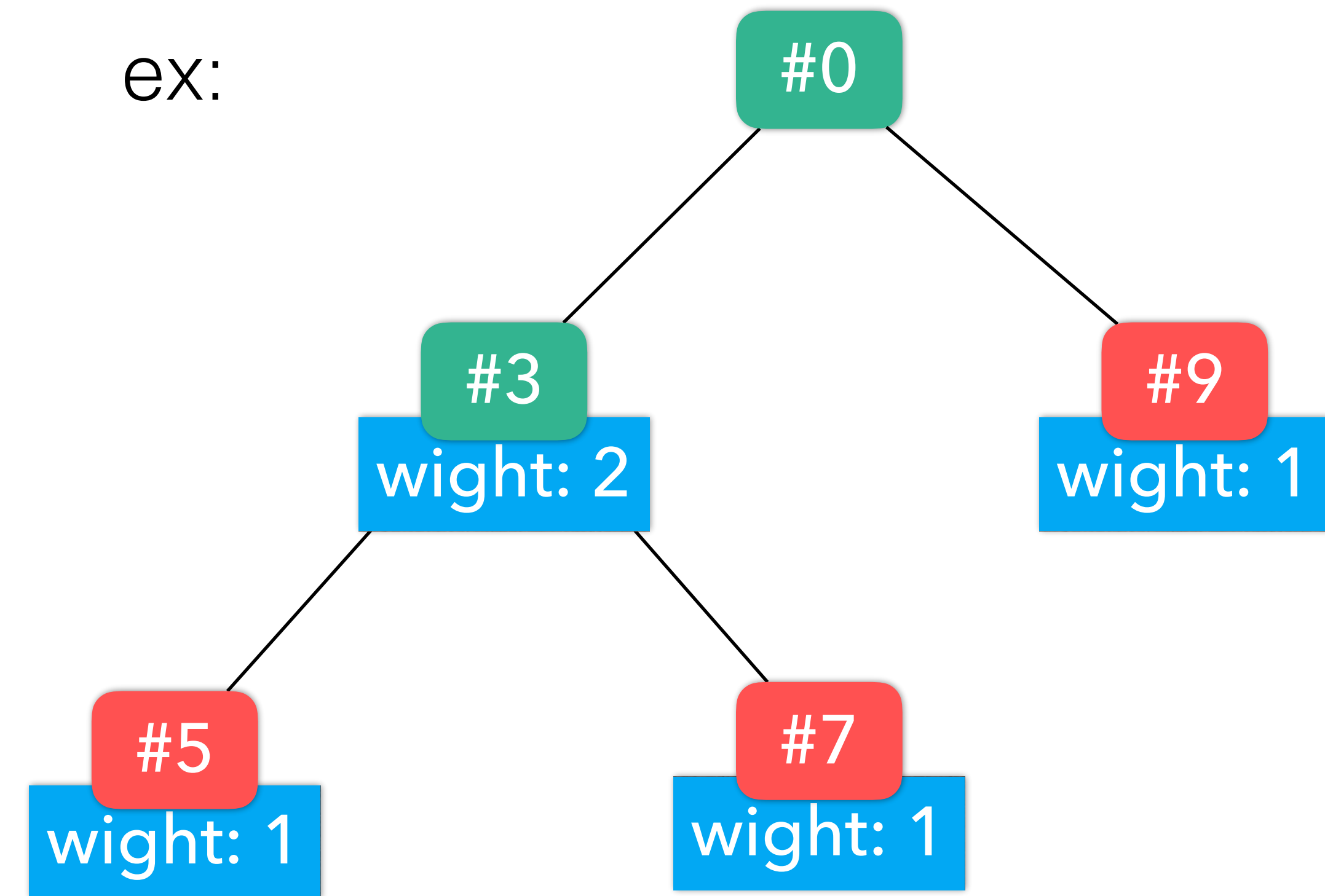


The PRIORITY frame specifies the sender-advised priority of a stream.

It can be sent in any stream state.

"Active" and "Inactive" Streams

ex:

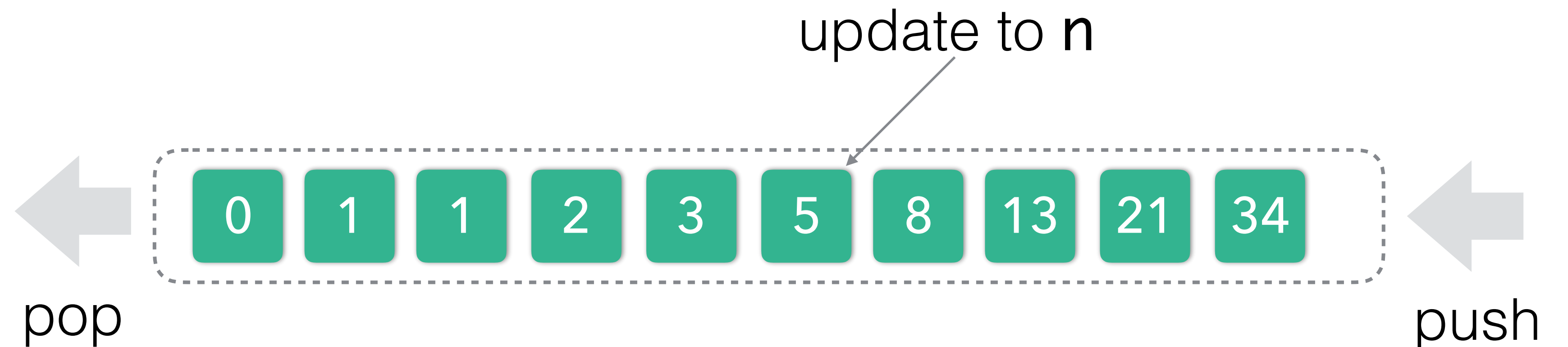


- If stream #3 is not used for requests and responses, it's OK.

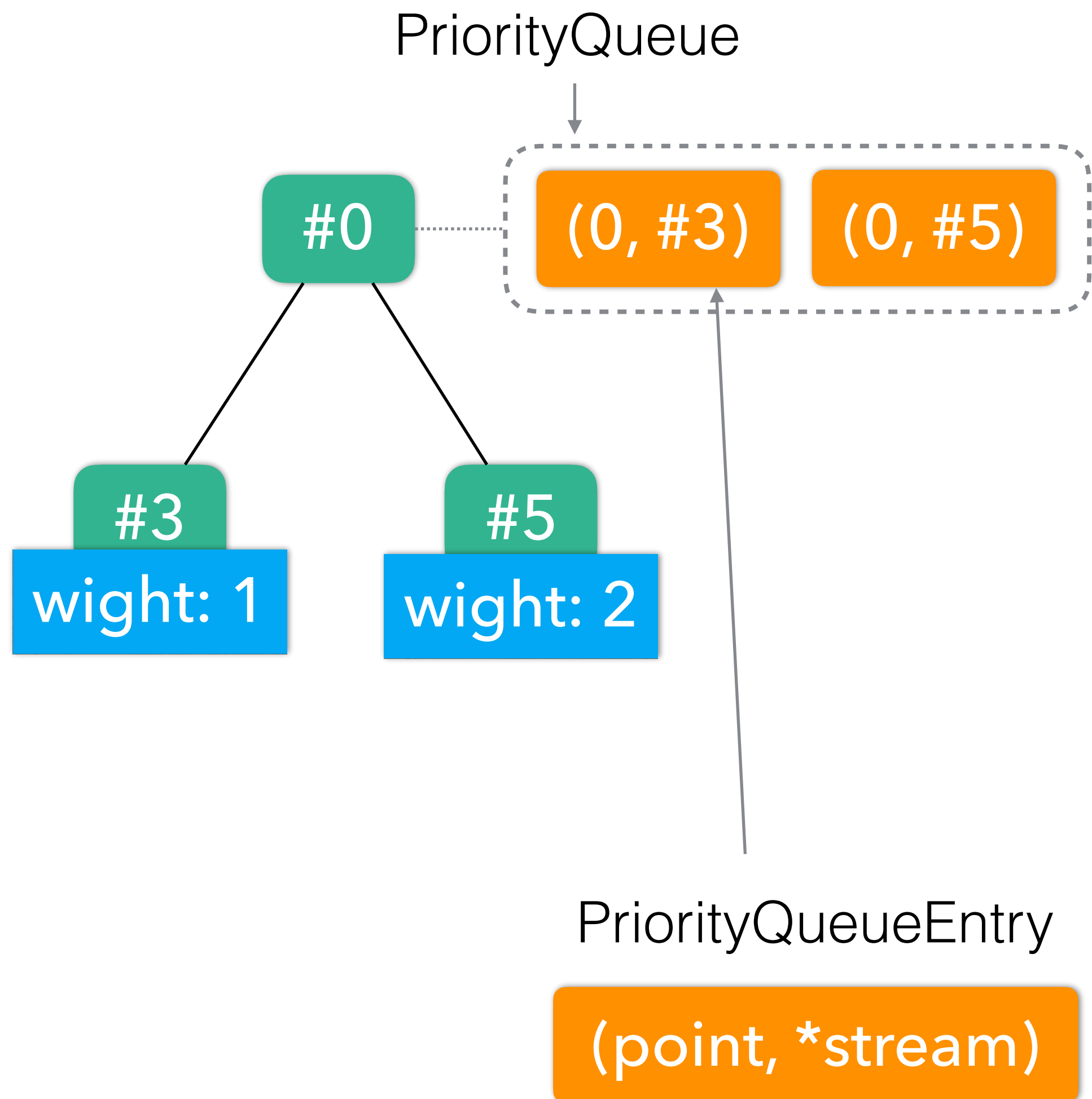
2. Algorithms and Implementations

lib/ts/PriorityQueue.h

- Using Simple Binary Heap (default: min heap)
- Interfaces are little bit similar to `std::priority_queue` (top/pop/push)
- But we can **update** point of entry



Weighted Fair Queuing

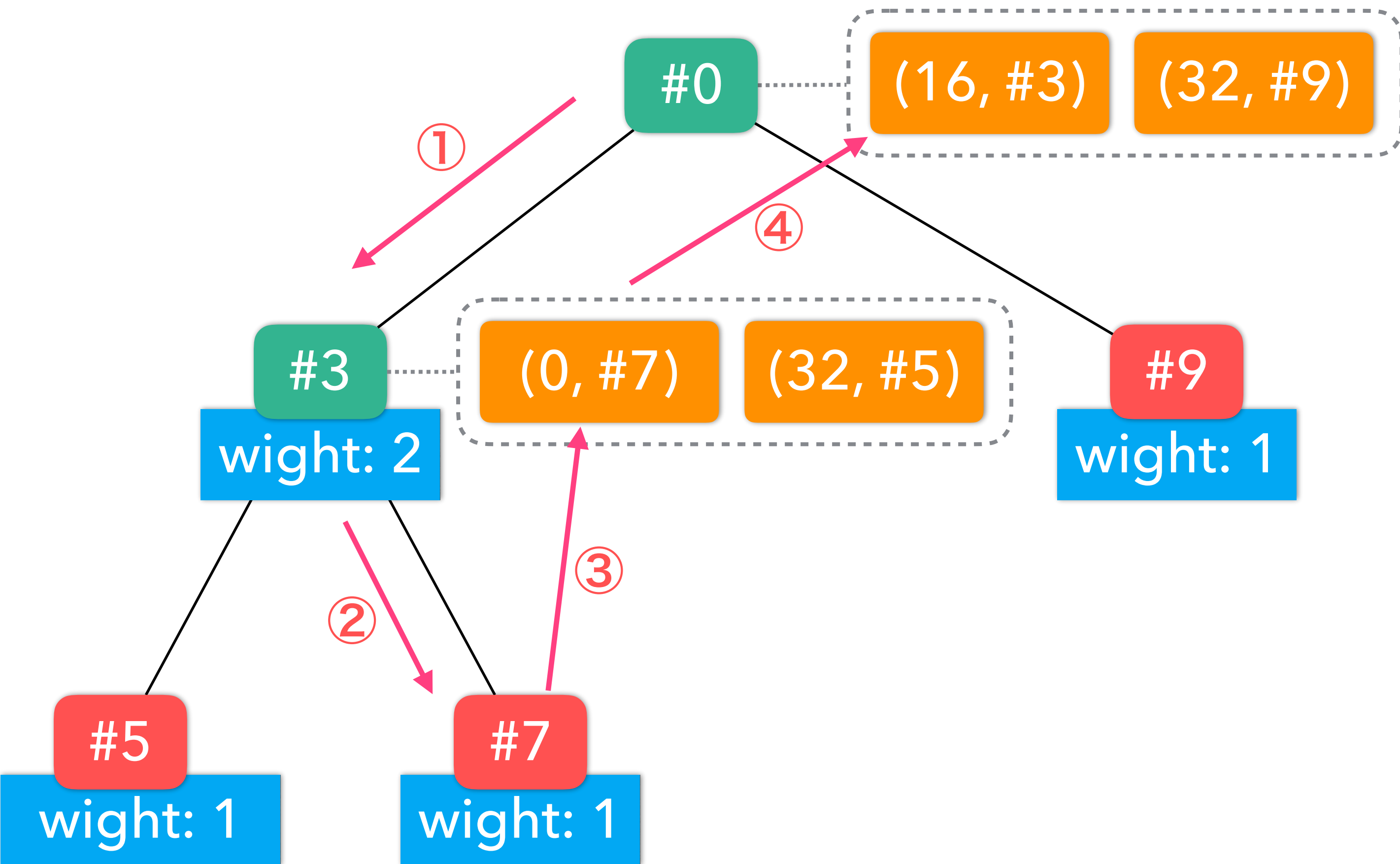


- Parent node has PriorityQueue.
- When a child node is ready, an entry for the node is pushed to PriorityQueue.
- When schedule streams, top entry of PriorityQueue is popped, sent response body and update point with below calculation.

```
point += sent_length * K / weight
```

(K is constant number)

Dependency Tree



- Intermediate node(#3) has PriorityQueue.
- Start from #0, get top node of PriorityQueue in each level, Stop when get active node.
- Update point of entries in PriorityQueue recursively.

Notes

- The algorithm of scheduling streams using WFQ is came from h2o project and introduced by Kazu Yamamoto (warp) and Tatsuhiro Tsujikawa (nghttp2) at ATS Meetup in Tokyo 2015.
- Server Implementations of HTTP/2 Priority
- HTTP/2 priority implementation in nghttp2

ATS specific notes

- Currently only DATA frames are scheduled.
 - Almost all of HEADERS frames could be put in one frame (16KB)
- After every one DATA frame is written in buffer, an event is scheduled and go back to event-system.
 - To check if there are any new active node is available.

Scheduling DATA frames

eventsystem

Http2ConnectionState

Http2DependencyTree

Http2Stream #3

Http2Stream #5

process VC_EVENT_WRITE_* event

activate a node of Http2DependencyTree

schedule XMIT event

process XMIT event

write a DATA frame

schedule XMIT event

process VC_EVENT_WRITE_* event

activate a node of Http2DependencyTree

schedule XMIT event

process XMIT event

write a DATA frame

3. Performance Tests

Performance Test

- Origin Server : HTTP2Rulez! is served from Apache
 - <https://github.com/ipeychev/http2rulez.com>
 - All contents are cacheable
 - Cache-Control: public, max-age=86400
- ATS : master(v7.0.0-pre) vs TS-3535 patch
- Client : Chrome 50.0.2661.86 / FireFox 46.0.1
 - Browser-Cache is disabled

ATS-v7.0.0-pre(Chrome 50.0.2661.94)

Name	Status	Protocol	Type	Initiator	Size	Time	Cache-Control	Server	Timeline - Start Time	400.00 ms	600.00 ms	800.00 ms	1.00 s
index.html	200	h2	document	Other	3.6 KB	29 ms	public, max-age=86...	ATS/7.0...					
bootstrap.css	200	h2	stylesheet	index.html:14	19.1 KB	69 ms	public, max-age=86...	ATS/7.0...					
magnific-popup.css	200	h2	stylesheet	index.html:17	1.9 KB	71 ms	public, max-age=86...	ATS/7.0...					
font-awesome.css	200	h2	stylesheet	index.html:20	4.9 KB	76 ms	public, max-age=86...	ATS/7.0...					
header.css	200	h2	stylesheet	index.html:23	181 B	77 ms	public, max-age=86...	ATS/7.0...					
main.css	200	h2	stylesheet	index.html:24	759 B	77 ms	public, max-age=86...	ATS/7.0...					
country-1170x400.jpeg	200	h2	jpeg	index.html:141	61.9 KB	176 ms	public, max-age=86...	ATS/7.0...					
boat-1170x400.jpeg	200	h2	jpeg	index.html:144	55.8 KB	198 ms	public, max-age=86...	ATS/7.0...					
snow-1170x400.jpeg	200	h2	jpeg	index.html:147	99.2 KB	230 ms	public, max-age=86...	ATS/7.0...					
beach-1170x400.jpeg	200	h2	jpeg	index.html:150	51.3 KB	248 ms	public, max-age=86...	ATS/7.0...					
glass-building-1170x400.jpeg	200	h2	jpeg	index.html:153	77.6 KB	270 ms	public, max-age=86...	ATS/7.0...					
person_3.png	200	h2	png	index.html:172	54.7 KB	286 ms	public, max-age=86...	ATS/7.0...					
rila_small.jpg	200	h2	jpeg	index.html:193	191 KB	347 ms	public, max-age=86...	ATS/7.0...					
varna.jpeg	200	h2	jpeg	index.html:214	134 KB	389 ms	public, max-age=86...	ATS/7.0...					
tsarevets_small.jpg	200	h2	jpeg	index.html:235	173 KB	445 ms	public, max-age=86...	ATS/7.0...					
london.jpeg	200	h2	jpeg	index.html:256	29.8 KB	451 ms	public, max-age=86...	ATS/7.0...					
cibeles_small.jpg	200	h2	jpeg	index.html:277	113 KB	490 ms	public, max-age=86...	ATS/7.0...					
recife_small.jpg	200	h2	jpeg	index.html:298	145 KB	564 ms	public, max-age=86...	ATS/7.0...					
tree.jpeg	200	h2	jpeg	index.html:319	82.0 KB	572 ms	public, max-age=86...	ATS/7.0...					
san-fran.jpeg	200	h2	jpeg	index.html:340	21.6 KB	578 ms	public, max-age=86...	ATS/7.0...					
cheetah.jpeg	200	h2	jpeg	index.html:361	53.7 KB	599 ms	public, max-age=86...	ATS/7.0...					
altscale-logo-200px.png	200	h2	png	index.html:398	7.3 KB	601 ms	public, max-age=86...	ATS/7.0...					
jquery-1.11.0.js	200	h2	script	index.html:406	32.6 KB	104 ms	public, max-age=86...	ATS/7.0...					
jquery-ui.min.js	200	h2	script	index.html:407	59.3 KB	141 ms	public, max-age=86...	ATS/7.0...					
bootstrap.min.js	200	h2	script	index.html:410	8.4 KB	142 ms	public, max-age=86...	ATS/7.0...					
jquery.magnific-popup.js	200	h2	script	index.html:412	13.5 KB	153 ms	public, max-age=86...	ATS/7.0...					
shuffle.js	200	h2	script	index.html:413	278 B	156 ms	public, max-age=86...	ATS/7.0...					
jquery.shapeshift.js	200	h2	script	index.html:414	5.7 KB	156 ms	public, max-age=86...	ATS/7.0...					
homepage.js	200	h2	script	index.html:415	508 B	157 ms	public, max-age=86...	ATS/7.0...					
profiler.js	200	h2	script	index.html:416	4.3 KB	157 ms	public, max-age=86...	ATS/7.0...					
glyphicons-halflings-regular.woff	200	h2	font	index.html:406	22.8 KB	516 ms	public, max-age=86...	ATS/7.0...					
fontawesome-webfont.woff?v=4.1.0	200	h2	font	index.html:406	81.9 KB	548 ms	public, max-age=86...	ATS/7.0...					

ATS-v7.0.0-pre with TS-3535 patch (Chrome 50.0.2661.94)

Name	Status	Protocol	Type	Initiator	Size	Time	Cache-Control	Server	Timeline – Start Time	400.00 ms	600.00 ms	800.00 ms	1.00 s
index.html	200	h2	document	Other	3.6 KB	28 ms	public, max-age=86...	ATS/7.0...					
bootstrap.css	200	h2	stylesheet	index.html:14	19.1 KB	141 ms	public, max-age=86...	ATS/7.0...					
magnific-popup.css	200	h2	stylesheet	index.html:17	1.9 KB	80 ms	public, max-age=86...	ATS/7.0...					
font-awesome.css	200	h2	stylesheet	index.html:20	4.9 KB	81 ms	public, max-age=86...	ATS/7.0...					
header.css	200	h2	stylesheet	index.html:23	189 B	81 ms	public, max-age=86...	ATS/7.0...					
main.css	200	h2	stylesheet	index.html:24	767 B	81 ms	public, max-age=86...	ATS/7.0...					
country-1170x400.jpeg	200	h2	jpeg	index.html:141	61.9 KB	398 ms	public, max-age=86...	ATS/7.0...					
boat-1170x400.jpeg	200	h2	jpeg	index.html:144	55.8 KB	398 ms	public, max-age=86...	ATS/7.0...					
snow-1170x400.jpeg	200	h2	jpeg	index.html:147	99.2 KB	501 ms	public, max-age=86...	ATS/7.0...					
beach-1170x400.jpeg	200	h2	jpeg	index.html:150	51.3 KB	400 ms	public, max-age=86...	ATS/7.0...					
glass-building-1170x400.jpeg	200	h2	jpeg	index.html:153	77.6 KB	447 ms	public, max-age=86...	ATS/7.0...					
person_3.png	200	h2	png	index.html:172	54.7 KB	408 ms	public, max-age=86...	ATS/7.0...					
rila_small.jpg	200	h2	jpeg	index.html:193	191 KB	604 ms	public, max-age=86...	ATS/7.0...					
varna.jpeg	200	h2	jpeg	index.html:214	134 KB	567 ms	public, max-age=86...	ATS/7.0...					
tsarevets_small.jpg	200	h2	jpeg	index.html:235	173 KB	601 ms	public, max-age=86...	ATS/7.0...					
london.jpeg	200	h2	jpeg	index.html:256	29.8 KB	307 ms	public, max-age=86...	ATS/7.0...					
cibeles_small.jpg	200	h2	jpeg	index.html:277	113 KB	557 ms	public, max-age=86...	ATS/7.0...					
recife_small.jpg	200	h2	jpeg	index.html:298	145 KB	586 ms	public, max-age=86...	ATS/7.0...					
tree.jpeg	200	h2	jpeg	index.html:319	82.0 KB	498 ms	public, max-age=86...	ATS/7.0...					
san-fran.jpeg	200	h2	jpeg	index.html:340	21.6 KB	322 ms	public, max-age=86...	ATS/7.0...					
cheetah.jpeg	200	h2	jpeg	index.html:361	53.7 KB	436 ms	public, max-age=86...	ATS/7.0...					
altscale-logo-200px.png	200	h2	png	index.html:398	7.3 KB	250 ms	public, max-age=86...	ATS/7.0...					
jquery-1.11.0.js	200	h2	script	index.html:406	32.6 KB	156 ms	public, max-age=86...	ATS/7.0...					
jquery-ui.min.js	200	h2	script	index.html:407	59.3 KB	175 ms	public, max-age=86...	ATS/7.0...					
bootstrap.min.js	200	h2	script	index.html:410	8.4 KB	123 ms	public, max-age=86...	ATS/7.0...					
jquery.magnific-popup.js	200	h2	script	index.html:412	13.5 KB	123 ms	public, max-age=86...	ATS/7.0...					
shuffle.js	200	h2	script	index.html:413	286 B	134 ms	public, max-age=86...	ATS/7.0...					
jquery.shapeshift.js	200	h2	script	index.html:414	5.7 KB	134 ms	public, max-age=86...	ATS/7.0...					
homepage.js	200	h2	script	index.html:415	516 B	135 ms	public, max-age=86...	ATS/7.0...					
profiler.js	200	h2	script	index.html:416	4.3 KB	181 ms	public, max-age=86...	ATS/7.0...					
glyphicons-halflings-regular.woff	200	h2	font	index.html:406	22.8 KB	457 ms	public, max-age=86...	ATS/7.0...					
fontawesome-webfont.woff?v=4.1.0	200	h2	font	index.html:406	81.9 KB	477 ms	public, max-age=86...	ATS/7.0...					

ATS-v7.0.0-pre (Firefox 46.0.1)

Status	Method	File	Domain	Type	Transfer...	Size	0 ms	320 ms	640 ms	960 ms
●	200	GET	index.html	mkshiba02.img.ssk.ynwm....	html	3.59 KB	24.02 KB	→ 77 ms		
●	200	GET	bootstrap.css	mkshiba02.img.ssk.ynwm....	css	19.02 KB	129.40 KB	→ 63 ms		
●	200	GET	magnific-popup.css	mkshiba02.img.ssk.ynwm....	css	1.89 KB	7.60 KB	→ 63 ms		
●	200	GET	font-awesome.css	mkshiba02.img.ssk.ynwm....	css	4.87 KB	24.61 KB	→ 74 ms		
●	200	GET	header.css	mkshiba02.img.ssk.ynwm....	css	0.15 KB	0.16 KB	→ 75 ms		
●	200	GET	main.css	mkshiba02.img.ssk.ynwm....	css	0.71 KB	1.57 KB	→ 75 ms		
●	200	GET	jquery-1.11.0.js	mkshiba02.img.ssk.ynwm....	js	32.59 KB	94.12 KB	→ 129 ms		
●	200	GET	jquery-ui.min.js	mkshiba02.img.ssk.ynwm....	js	59.21 KB	222.73 KB	→ 167 ms		
●	200	GET	bootstrap.min.js	mkshiba02.img.ssk.ynwm....	js	8.33 KB	31.07 KB	→ 168 ms		
●	200	GET	jquery.magnific-popup.js	mkshiba02.img.ssk.ynwm....	js	13.49 KB	44.80 KB	→ 182 ms		
●	200	GET	shuffle.js	mkshiba02.img.ssk.ynwm....	js	0.24 KB	0.42 KB	→ 181 ms		
●	200	GET	jquery.shapeshift.js	mkshiba02.img.ssk.ynwm....	js	5.70 KB	28.27 KB	→ 181 ms		
●	200	GET	homepage.js	mkshiba02.img.ssk.ynwm....	js	0.46 KB	0.84 KB	→ 181 ms		
●	200	GET	profiler.js	mkshiba02.img.ssk.ynwm....	js	4.28 KB	14.06 KB	→ 181 ms		
●	200	GET	country-1170x400.jpeg	mkshiba02.img.ssk.ynwm....	jpeg	61.81 KB	61.81 KB	→ 223 ms		
●	200	GET	boat-1170x400.jpeg	mkshiba02.img.ssk.ynwm....	jpeg	55.71 KB	55.71 KB	→ 267 ms		
●	200	GET	snow-1170x400.jpeg	mkshiba02.img.ssk.ynwm....	jpeg	99.16 KB	99.16 KB	→ 345 ms		
●	200	GET	beach-1170x400.jpeg	mkshiba02.img.ssk.ynwm....	jpeg	51.20 KB	51.20 KB	→ 374 ms		
●	200	GET	glass-building-1170x400.jpeg	mkshiba02.img.ssk.ynwm....	jpeg	77.49 KB	77.49 KB	→ 430 ms		
●	200	GET	person_3.png	mkshiba02.img.ssk.ynwm....	png	54.67 KB	54.67 KB	→ 461 ms		
●	200	GET	rila_small.jpg	mkshiba02.img.ssk.ynwm....	jpeg	190.69 KB	190.69 KB	→ 579 ms		
●	200	GET	varna.jpeg	mkshiba02.img.ssk.ynwm....	jpeg	134.36 KB	134.36 KB	→ 663 ms		
●	200	GET	tsarevets_small.jpg	mkshiba02.img.ssk.ynwm....	jpeg	173.20 KB	173.20 KB	→ 761 ms		
●	200	GET	london.jpeg	mkshiba02.img.ssk.ynwm....	jpeg	29.78 KB	29.78 KB	→ 784 ms		
●	200	GET	cibeles_small.jpg	mkshiba02.img.ssk.ynwm....	jpeg	112.69 KB	112.69 KB	→ 841 ms		
●	200	GET	recife_small.jpg	mkshiba02.img.ssk.ynwm....	jpeg	145.34 KB	145.34 KB	→ 924 ms		
●	200	GET	tree.jpeg	mkshiba02.img.ssk.ynwm....	jpeg	81.93 KB	81.93 KB	→ 965 ms		
●	200	GET	san-fran.jpeg	mkshiba02.img.ssk.ynwm....	jpeg	21.60 KB	21.60 KB	→ 981 ms		
●	200	GET	cheetah.jpeg	mkshiba02.img.ssk.ynwm....	jpeg	53.63 KB	53.63 KB	→ 1015 ms		
●	200	GET	altscale-logo-200px.png	mkshiba02.img.ssk.ynwm....	png	7.31 KB	7.31 KB	→ 1025 ms		
●	200	GET	glyphicons-halflings-regular.woff	mkshiba02.img.ssk.ynwm....	x-font-woff	22.77 KB	22.77 KB	→ 906 ms		
●	200	GET	fontawesome-webfont.woff?v=4.1.0	mkshiba02.img.ssk.ynwm....	x-font-woff	81.80 KB	81.80 KB	→ 958 ms		

All HTML CSS JS XHR Fonts Images Media Flash Other 32 requests, 2,078.80 KB, 1.20 s Clear

ATS-v7.0.0-pre with TS-3535 patch (Firefox 46.0.1)

Status	Method	File	Domain	Type	Transfer...	Size	0 ms	320 ms	640 ms	960 ms
200	GET	index.html	mkoshiba02.img.ssk.ynwm....	html	3.59 KB	24.02 KB	→ 75 ms			
200	GET	bootstrap.css	mkoshiba02.img.ssk.ynwm....	css	19.02 KB	129.40 KB	→ 52 ms			
200	GET	magnific-popup.css	mkoshiba02.img.ssk.ynwm....	css	1.89 KB	7.60 KB	→ 50 ms			
200	GET	font-awesome.css	mkoshiba02.img.ssk.ynwm....	css	4.87 KB	24.61 KB	→ 51 ms			
200	GET	header.css	mkoshiba02.img.ssk.ynwm....	css	0.15 KB	0.16 KB	→ 61 ms			
200	GET	main.css	mkoshiba02.img.ssk.ynwm....	css	0.71 KB	1.57 KB	→ 61 ms			
200	GET	jquery-1.11.0.js	mkoshiba02.img.ssk.ynwm....	js	32.59 KB	94.12 KB	→ 111 ms			
200	GET	jquery-ui.min.js	mkoshiba02.img.ssk.ynwm....	js	59.21 KB	222.73 KB	→ 126 ms			
200	GET	bootstrap.min.js	mkoshiba02.img.ssk.ynwm....	js	8.33 KB	31.07 KB	→ 128 ms			
200	GET	jquery.magnific-popup.js	mkoshiba02.img.ssk.ynwm....	js	13.49 KB	44.80 KB	→ 140 ms			
200	GET	shuffle.js	mkoshiba02.img.ssk.ynwm....	js	0.24 KB	0.42 KB	→ 140 ms			
200	GET	jquery.shapesift.js	mkoshiba02.img.ssk.ynwm....	js	5.70 KB	28.27 KB	→ 140 ms			
200	GET	homepage.js	mkoshiba02.img.ssk.ynwm....	js	0.46 KB	0.84 KB	→ 139 ms			
200	GET	profiler.js	mkoshiba02.img.ssk.ynwm....	js	4.28 KB	14.06 KB	→ 139 ms			
200	GET	country-1170x400.jpeg	mkoshiba02.img.ssk.ynwm....	jpeg	61.81 KB	61.81 KB	→ 171 ms			
200	GET	boat-1170x400.jpeg	mkoshiba02.img.ssk.ynwm....	jpeg	55.71 KB	55.71 KB	→ 202 ms			
200	GET	snow-1170x400.jpeg	mkoshiba02.img.ssk.ynwm....	jpeg	99.16 KB	99.16 KB	→ 245 ms			
200	GET	beach-1170x400.jpeg	mkoshiba02.img.ssk.ynwm....	jpeg	51.20 KB	51.20 KB	→ 267 ms			
200	GET	glass-building-1170x400.jpeg	mkoshiba02.img.ssk.ynwm....	jpeg	77.49 KB	77.49 KB	→ 394 ms			
200	GET	person_3.png	mkoshiba02.img.ssk.ynwm....	png	54.67 KB	54.67 KB	→ 363 ms			
200	GET	rila_small.jpg	mkoshiba02.img.ssk.ynwm....	jpeg	190.69 KB	190.69 KB	→ 490 ms			
200	GET	varna.jpeg	mkoshiba02.img.ssk.ynwm....	jpeg	134.36 KB	134.36 KB	→ 471 ms			
200	GET	tsarevets_small.jpg	mkoshiba02.img.ssk.ynwm....	jpeg	173.20 KB	173.20 KB	→ 573 ms			
200	GET	london.jpeg	mkoshiba02.img.ssk.ynwm....	jpeg	29.78 KB	29.78 KB	→ 588 ms			
200	GET	cibeles_small.jpg	mkoshiba02.img.ssk.ynwm....	jpeg	112.69 KB	112.69 KB	→ 769 ms			
200	GET	recife_small.jpg	mkoshiba02.img.ssk.ynwm....	jpeg	145.34 KB	145.34 KB	→ 776 ms			
200	GET	tree.jpeg	mkoshiba02.img.ssk.ynwm....	jpeg	81.93 KB	81.93 KB	→ 768 ms			
200	GET	san-fran.jpeg	mkoshiba02.img.ssk.ynwm....	jpeg	21.60 KB	21.60 KB	→ 791 ms			
200	GET	cheetah.jpeg	mkoshiba02.img.ssk.ynwm....	jpeg	53.63 KB	53.63 KB	→ 828 ms			
200	GET	altscale-logo-200px.png	mkoshiba02.img.ssk.ynwm....	png	7.31 KB	7.31 KB	→ 829 ms			
200	GET	glyphicons-halfings-regular.woff	mkoshiba02.img.ssk.ynwm....	x-font-woff	22.77 KB	22.77 KB	→ 719 ms			
200	GET	fontawesome-webfont.woff?v=4.1.0	mkoshiba02.img.ssk.ynwm....	x-font-woff	81.80 KB	81.80 KB	→ 759 ms			

All HTML CSS JS XHR Fonts Images Media Flash Other 32 requests, 2,078.80 KB, 1.00 s Clear

ATS-v7.0.0-pre

- TTFB (Time To First Byte) is increased gradually
- TS returns response body as much as possible

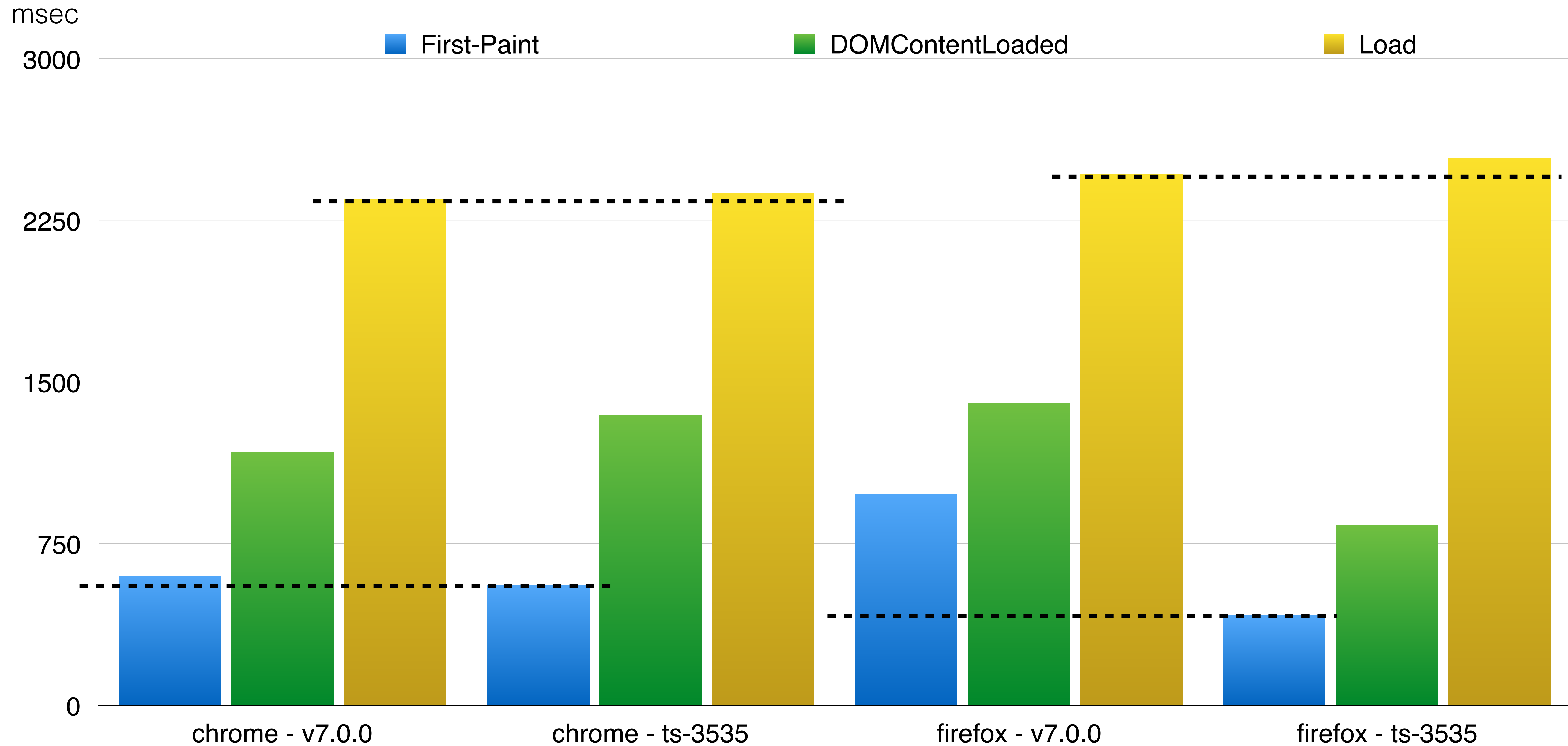
ATS-v7.0.0-pre with TS-3535

- Total duration is almost same (over heads looks little)
- TTFB (Time To First Byte) is not increased gradually
- Content Download duration is increased

First-Paint Time Benchmark

- Server Side : `sudo tc qdisc replace dev eth0 root netem delay 100ms`
- firstPaint.js from Browsertime
(<https://github.com/tobli/browsertime>)
- Chrome has a API to get First-Paint time but FireFox doesn't
https://bugzilla.mozilla.org/show_bug.cgi?id=1210906
- Average of 10 requests / responses

First-Paint Time (latency: 100msec)



Conclusion

- In some cases, Stream Priority Feature might improve User Experiences by decreasing First-Paint time.
- Note that it's trade-off (overheads are there)
- We need more test and performance improve.

4. Issues / Questions / Discussions

Issues / Questions / Discussions

Designs

- Is there any more good design of scheduling DATA frames?

Policies

- Should TS ignore client's advice when it is looks bad?
- And how to detect it?

YAHOO!
JAPAN

Appendix

- Understanding HTTP/2 prioritization
<https://speakerdeck.com/summerwind/2-prioritization>
- Server Implementations of HTTP/2 Priority
<http://www.mew.org/~kazu/material/2015-http2-priority2.pdf>
- HTTP/2 priority implementation in nghttp2
<https://goo.gl/3sSHXJ>
- http2rulez!
<https://github.com/ipeychev/http2rulez.com>
- Browsertime
<http://browsertime.net>