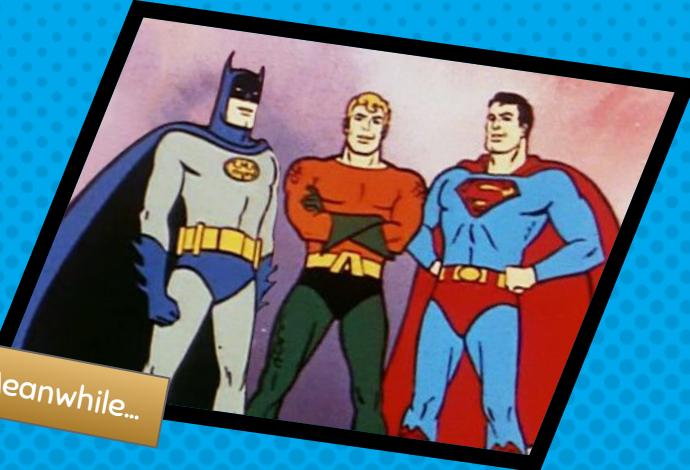


QUIC: in Theory and Practice

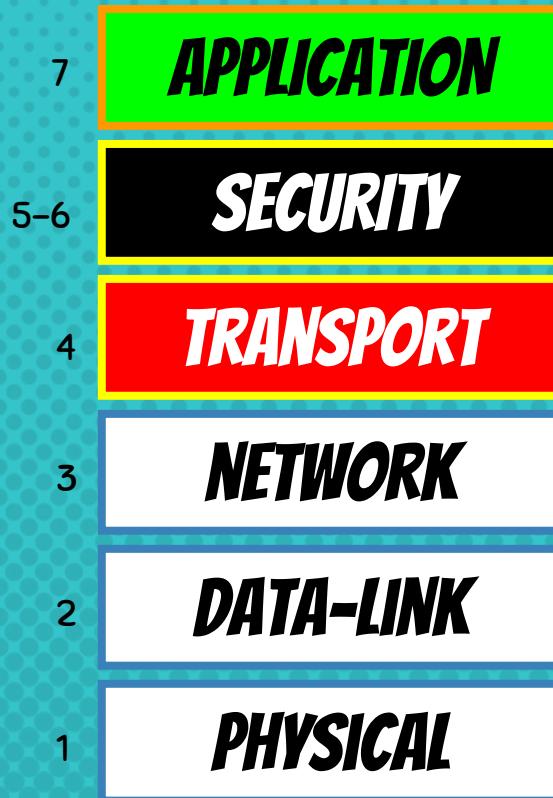


Q uick
U DP
I nternet
C onnections



THE FASTEST MAN AL

A QUAMAN
BRUCE WAYNE
IVE
C OMBINED



HTTP

TLS

TCP

IP

WIFI/4G

7
5-6
4
3
2
1

APPLICATION

SECURITY

TRANSPORT

NETWORK

DATA-LINK

PHYSICAL

HTTP

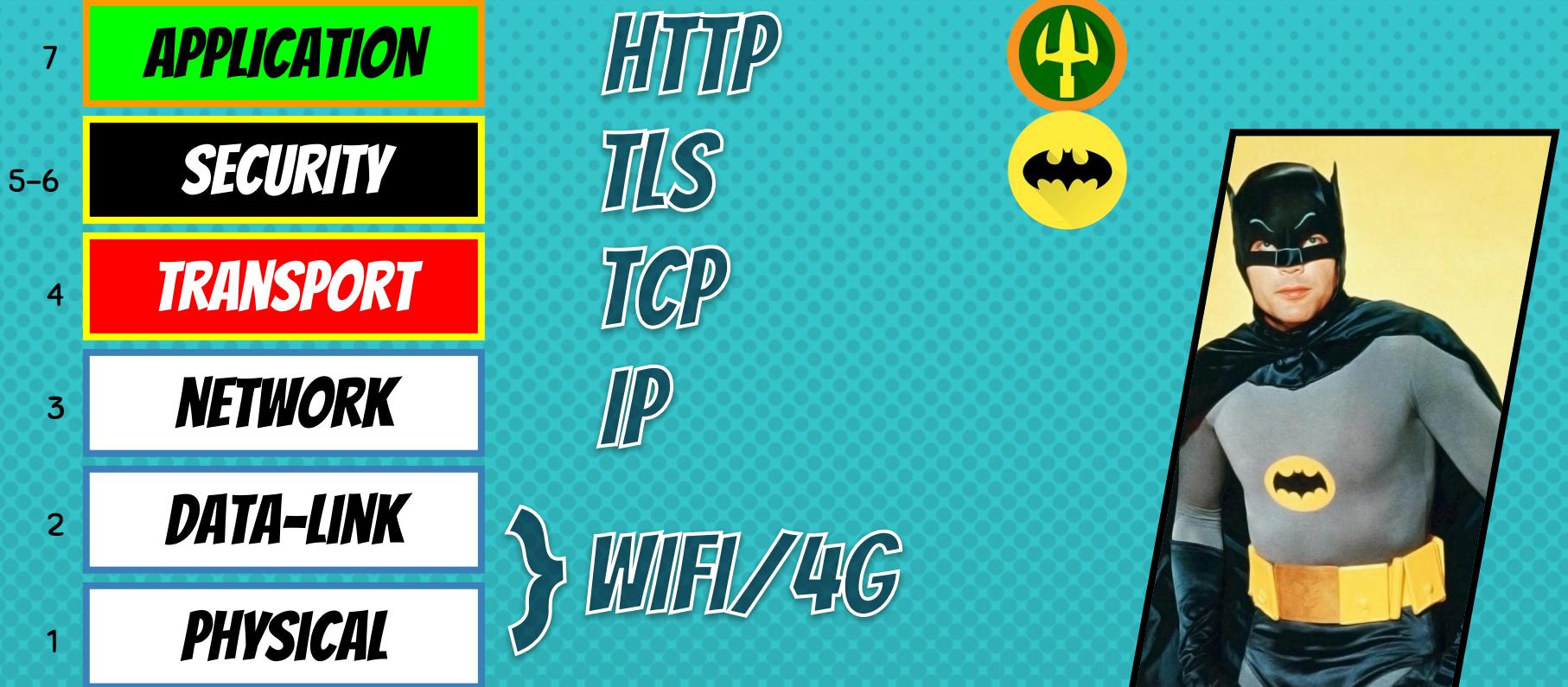
TLS

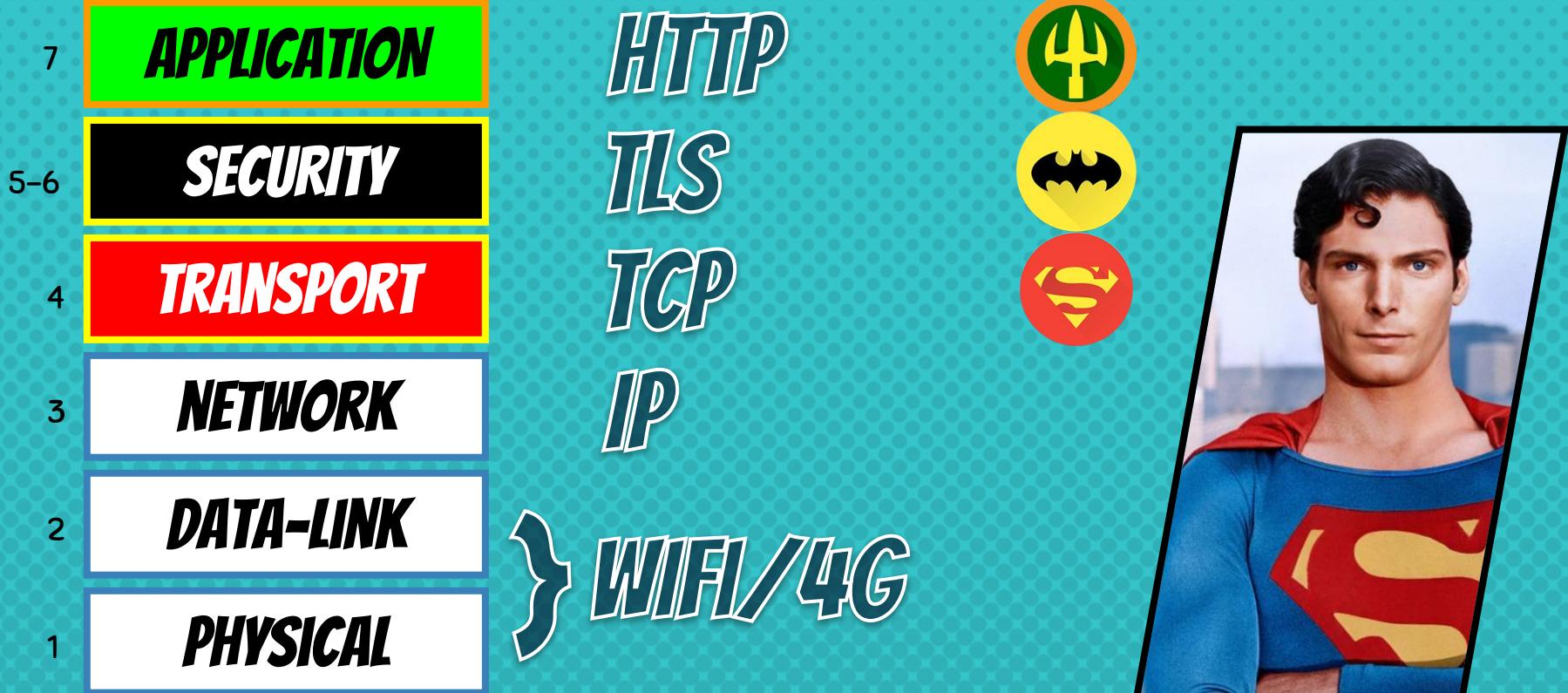
TCP

IP

WIFI/4G









in I got home Jan. 2nd the little
cystoma he has cut him open
rapidly & the doctors made
him to bed & the physician
of State came twice & had
& our own dr. daily & he
had a trained nurse to
sit up to night. he had been
in bed 5 weeks & then we
got down here by easy stages
he has very heart & his
nerves very bad I am glad
to say the fine dry air is
working wonders the jerking of his limbs is
going off & he sleeps without
any help. he suffers so
from insomnia. he has worked
for too hard & taken little
rest. after this he will have
to take things easier. If
father was born tho same
year as my husband. I am
a year older. after 3 weeks
here we go on to Lexington





TCP SYN/ACK



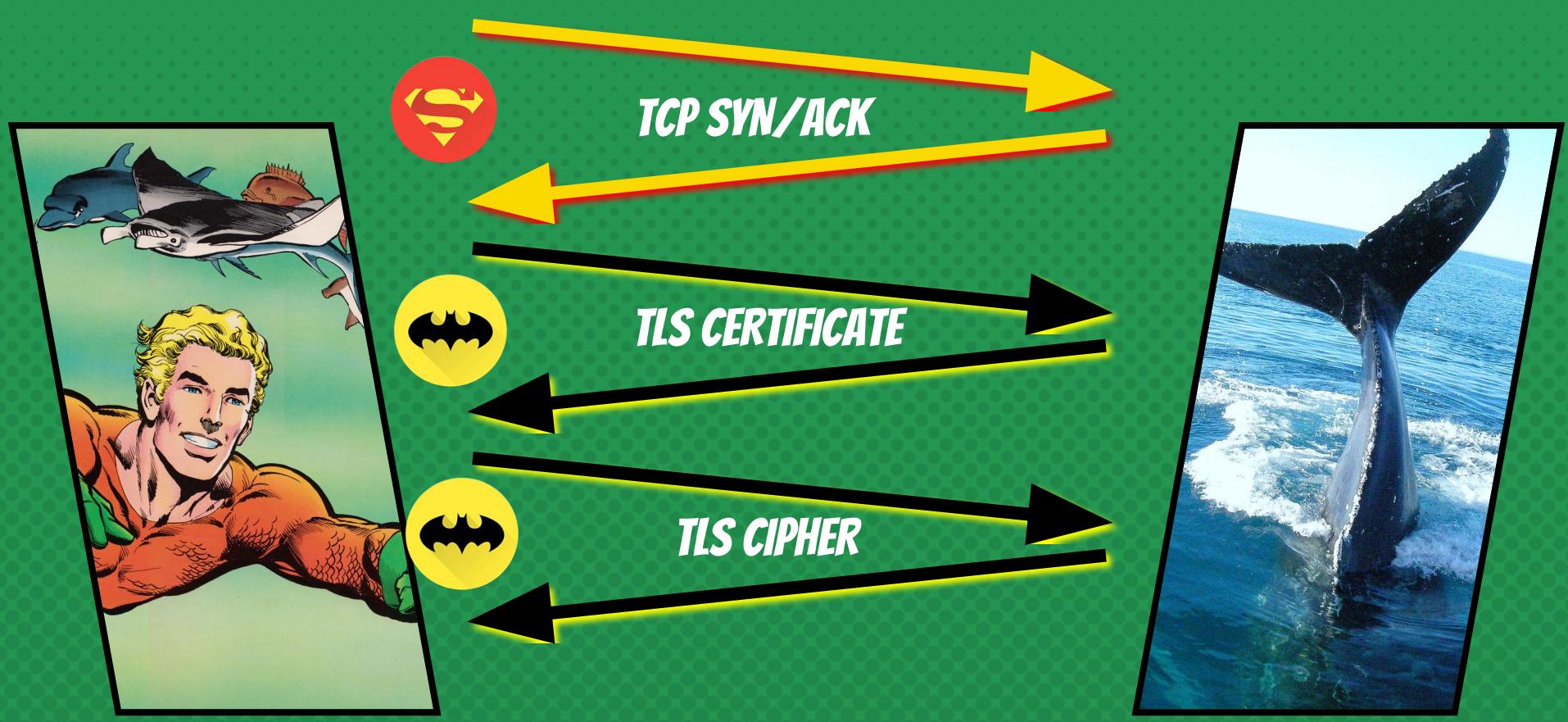


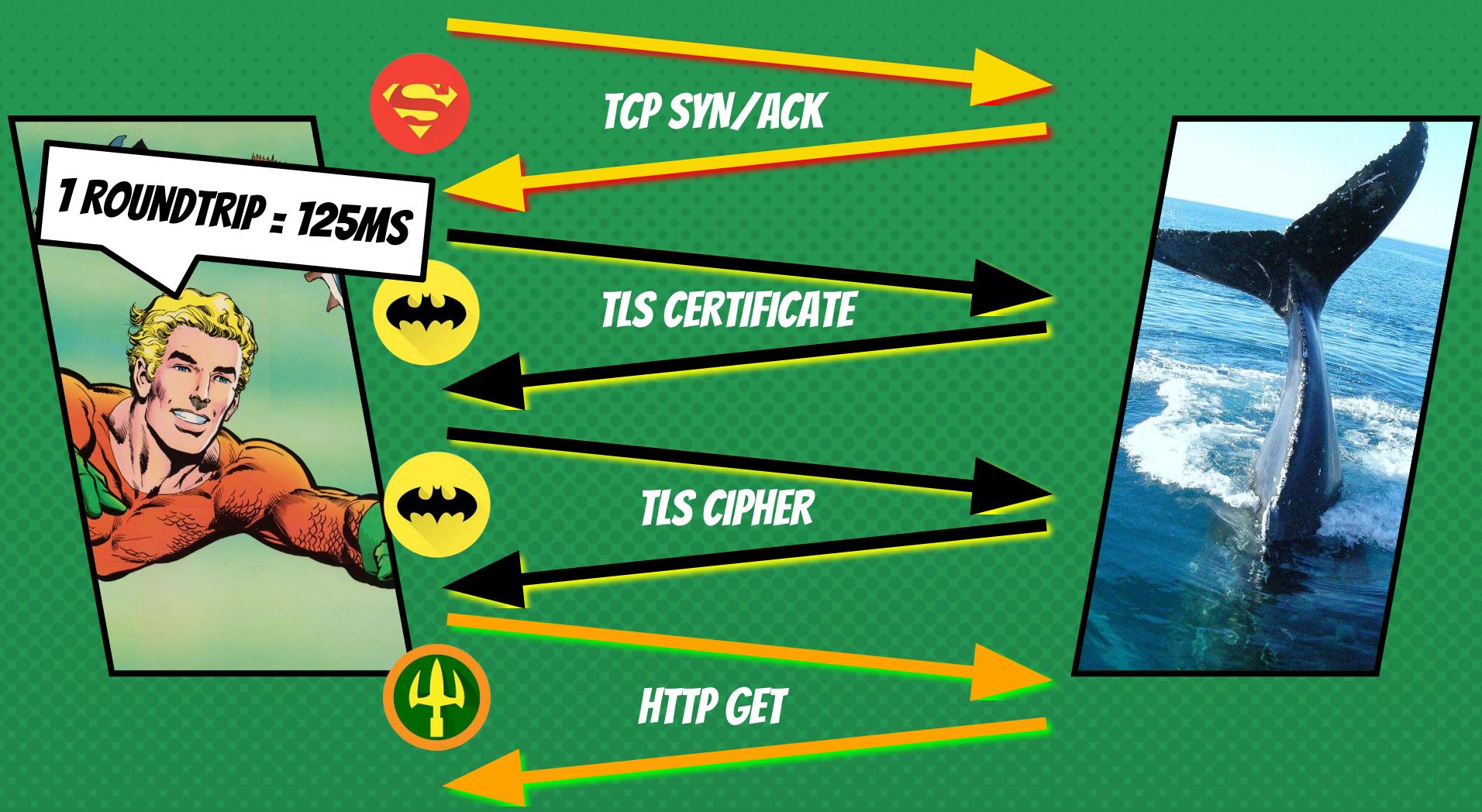
TCP SYN/ACK



TLS CERTIFICATE





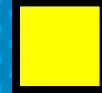




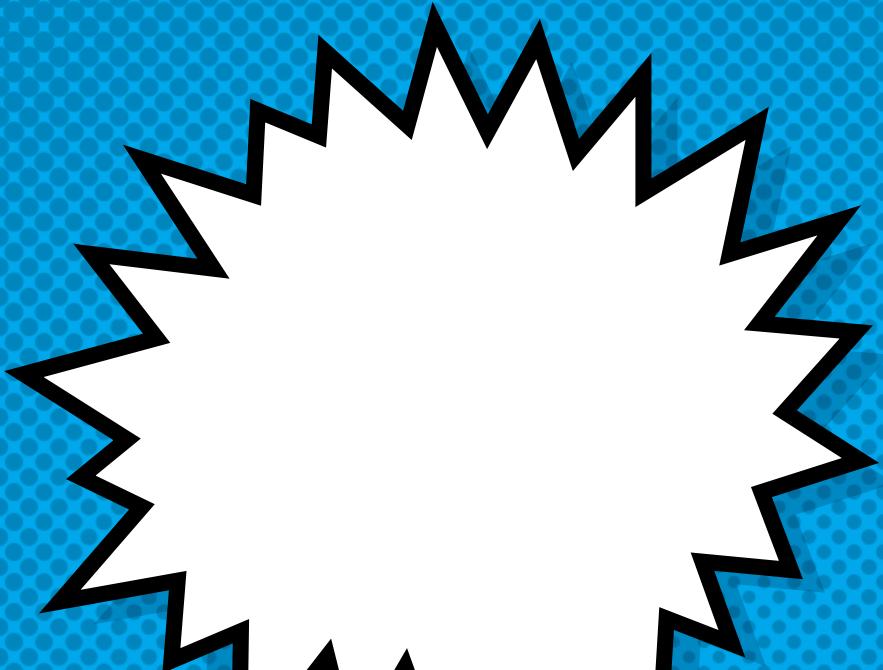
WANDA



POKER



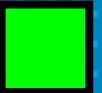
SPONGEBOB



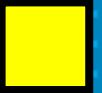
INDEX.HTML



MAIN.JS



STYLE.CSS





WANDA



POKER



SPONGEBOB

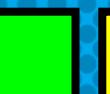
INDEX.HTML



MAIN.JS



STYLE.CSS





WANDA



POKER



SPONGEBOB

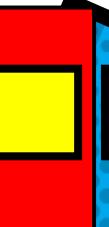
INDEX.HTML



MAIN.JS



STYLE.CSS





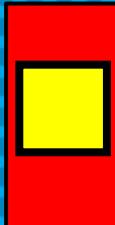
WANDA



POKER



SPONGEBOB



INDEX.HTML



MAIN.JS



STYLE.CSS





WANDA



POKER



SPONGEBOB



INDEX.HTML



MAIN.JS



STYLE.CSS





WANDA



POKER



SPONGEBOB



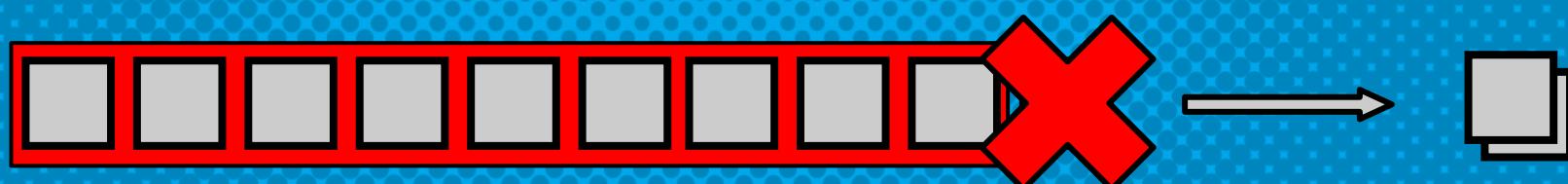
INDEX.HTML



MAIN.JS



STYLE.CSS





WANDA

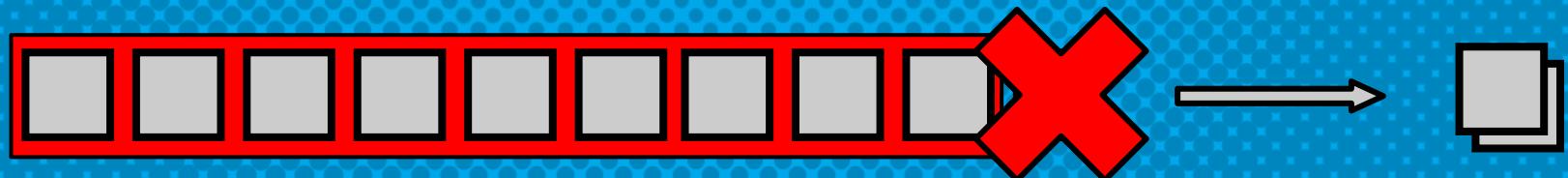


POKER



SPONGEBOB

TCP HEAD-OF-LINE BLOCKING



INDEX.HTML



MAIN.JS



STYLE.CSS





WANDA



POKER



SPONGEBOB



INDEX.HTML



MAIN.JS



STYLE.CSS





WANDA



POKER



SPONGEBOB



INDEX.HTML



MAIN.JS



STYLE.CSS





WANDA



POKER



SPONGEBOB



INDEX.HTML



MAIN.JS



STYLE.CSS



WANDA



POKER



SPONGEBOB

HTTP HEAD-OF-LINE BLOCKING



INDEX.HTML



MAIN.JS



STYLE.CSS







1

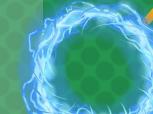
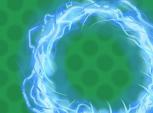
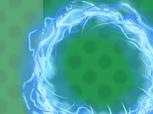
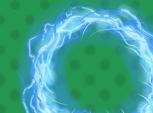
2

3

4

5

6





1

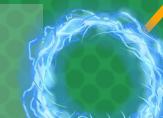
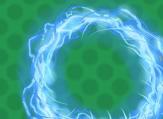
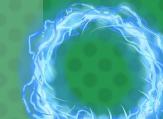
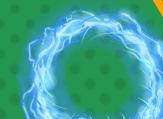
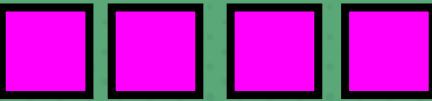
2

3

4

5

6



PROBLEMS THREE

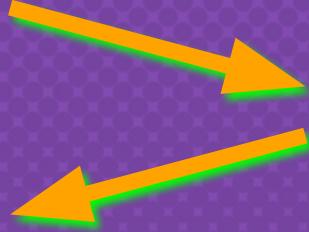
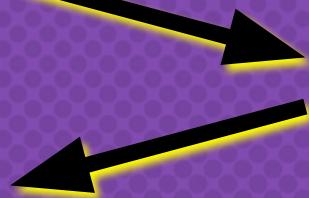
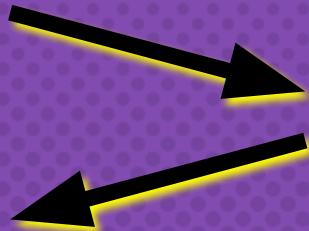
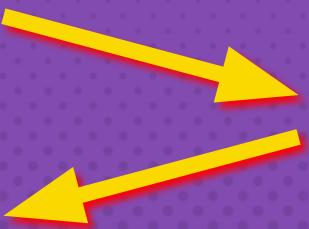
- 1. 4-RTT connection setup
- 2. TCP head-of-line blocking
- 3. HTTP head-of-line blocking

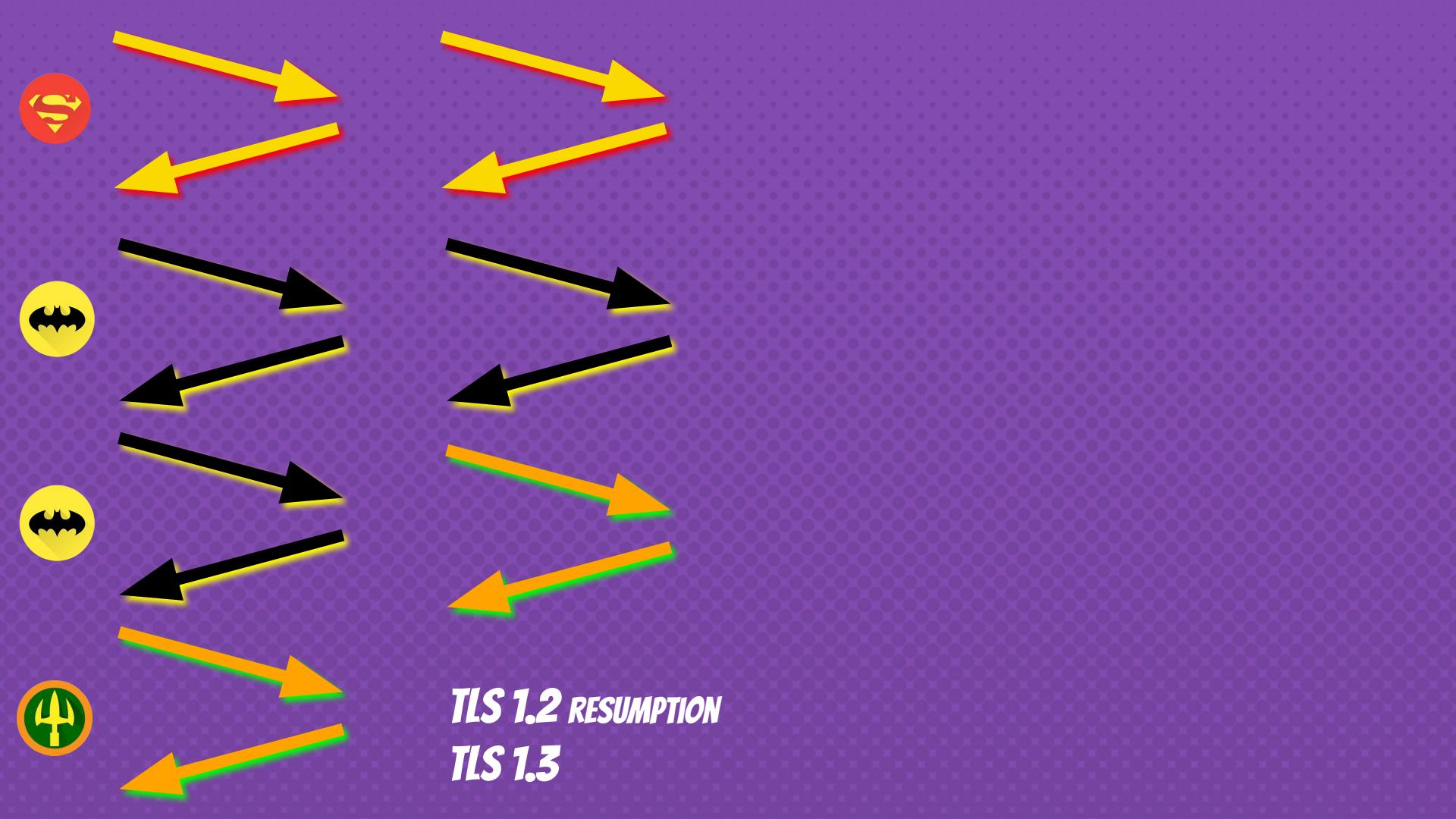
}

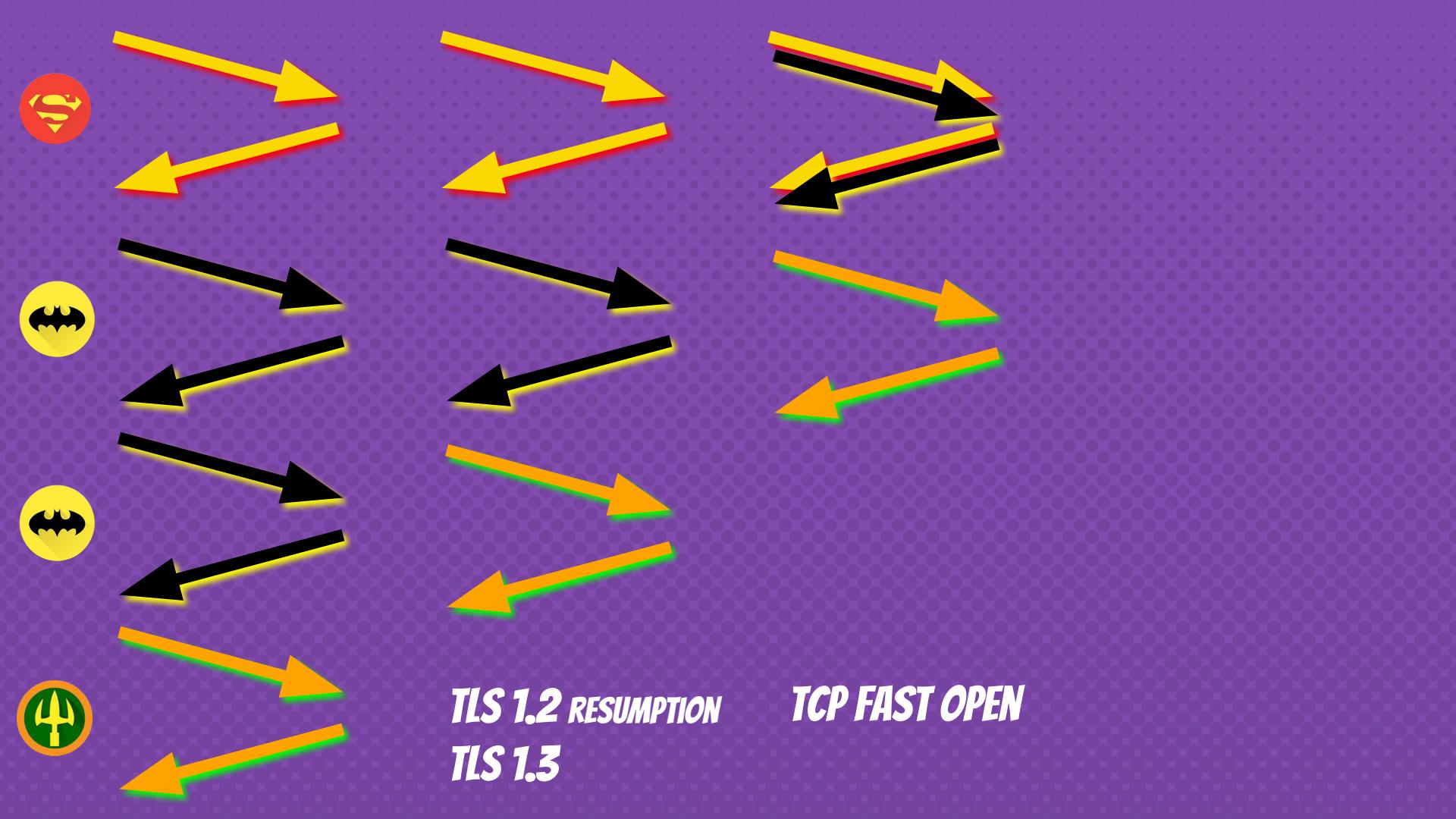
Parallel connections



TLS 1.2

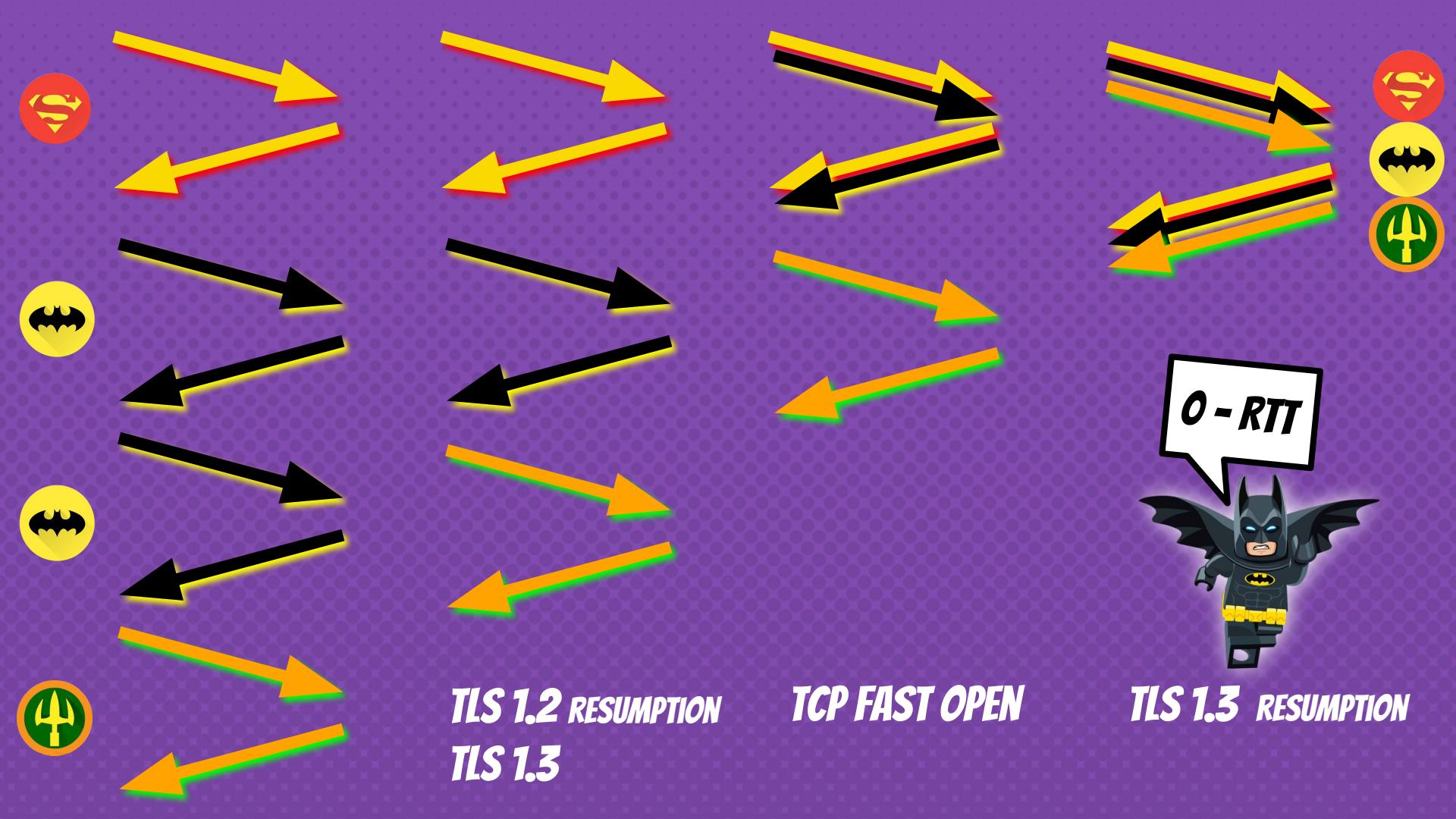






TLS 1.2 RESUMPTION
TLS 1.3

TCP FAST OPEN



TLS 1.2 RESUMPTION
TLS 1.3

TCP FAST OPEN

TLS 1.3 RESUMPTION

0 - RTT



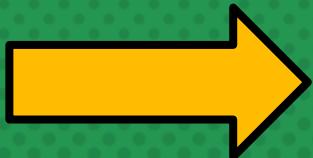
1.2



TLS



1.3



HTTP

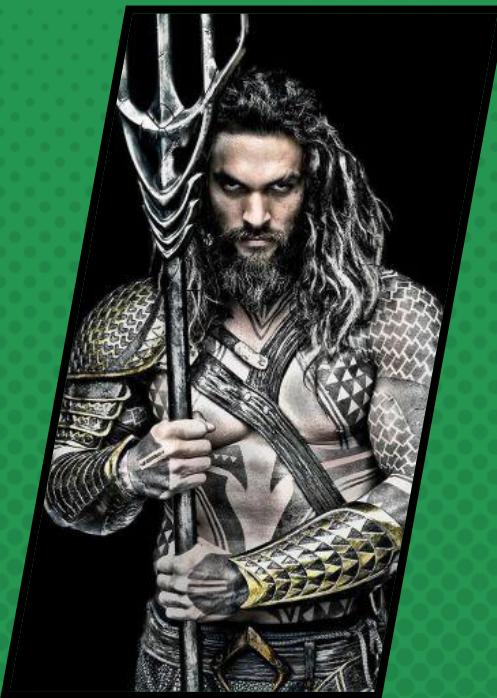
1.1



1.1



HTTP



2

Bath March 6th

My dear Mary. We have felt
very much for you all in
yesterday, you here all so
devotedly attached to your
dear good father. I fear this
will be a sad blow to your
dear Mother who is so little
able to bear it. As soon as
I saw the outside of the
paper bearing the sad tidings
I said there is to tell us of
cousin Georges death I do
it proved - my husband
was much affected as
he was ill at the time,
he got worse & when the
Funeral card came I
had to keep it from him.
He was ill in Oct. & Nov.
& Dec 2nd we all went
down to Bournemouth to
see if the rest & warmth
will do him good. He stayed
till after the new year came

so I got home Jan. 2nd the little
changes he has got. him off
rapidly & the doctors now
have him to bed & the physician
of State came twice & had
& our own Dr. daily & he
had a trained nurse to
sit up to night. He has been
in bed 5 weeks & then we
got down here by easy stages
he has very weak & his
nerves very bad I am glad
to say the fine dry air is
working wonders the jerking
of his limbs is
going off & he sleeps without
any help. He suffers so
from insomnia. He has worked
for too hard & taken little
rest. After this he will have
to take things easier. If
father was born the same
year as my husband I am
a year older. After 3 weeks
here we go on to Leamington

Saw my son here in Eng. last
summer. The 2 baby's I am
now a come to us in May
for 3 mos. The boy is 2 years
old & the sweetest child
I ever saw & so intelligent
his grandfather & I & all
are devoted to him & the
good sweet looking young
Mother. See & hope to see
her to come in 1900 as
she will have been in
China 7 years I think
but its will not be for a
few months I have a
fearful parting for us.
When you write tell me about
her & farm now I expect
some of yr bros. I send
the him to Greytown of
Mr. Wm. Edwards we
had to have a photo.
But I expect yr dear father
in the same attire
before he left you.
I wonder if John Newchurch

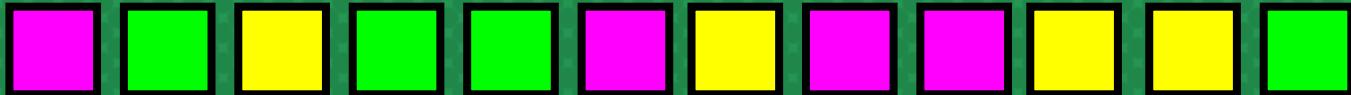
Lorem ipsum dolor sit amet, consectetur adipiscing elit. In sed velit urna. Vivamus lectus est, facilisis in imperdiet nec, tempus quis turpis. Morbi posuere leo sit amet mi mattis, sed sollicitudin diam porttitor. Curabitur sed orci urna. Donec tincidunt ligula eget eros rhoncus, a maximus erat fermentum. Curabitur pharetra tempus ante non aliquet. Nulla efficitur metus vulputate felis suscipit, in hendrerit ipsum venenatis. Praesent ut nunc facilisis, convallis lacus eu, egestas ante.

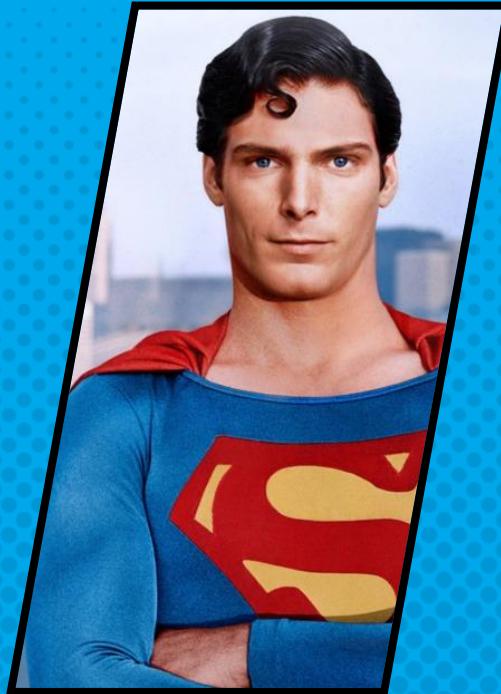


SPONGEBOB

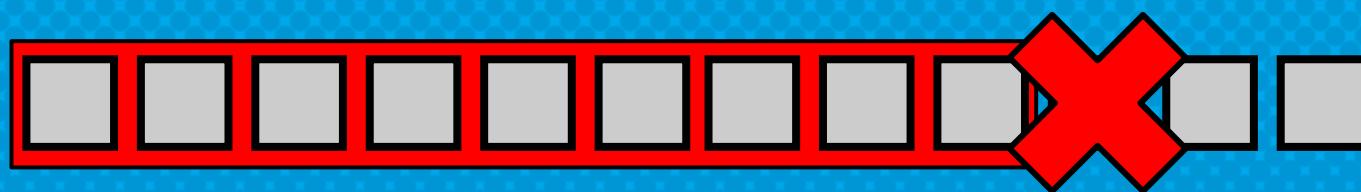
STYLE.CSS

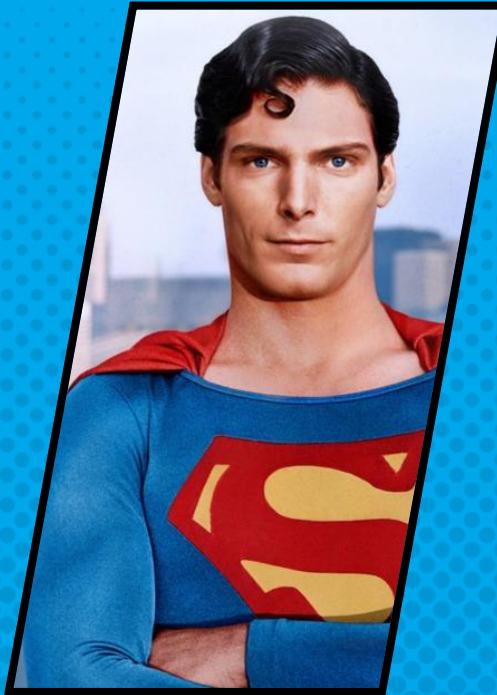
Lorem ipsum dolor sit amet, consectetur adipiscing elit. In sed velit urna. Vivamus lectus est, facilisis in imperdiet nec, tempus quis turpis. Morbi posuere leo sit amet mi mattis, sed sollicitudin diam porttitor. Curabitur sed orci urna. Donec tincidunt ligula eget eros rhoncus, a maximus erat fermentum. Curabitur pharetra tempus ante non aliquet. Nulla efficitur metus vulputate felis suscipit, in hendrerit ipsum venenatis. Praesent ut nunc facilisis, convallis lacus eu, egestas ante.



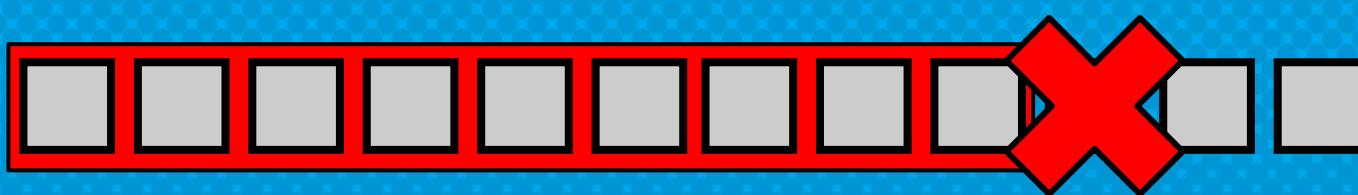
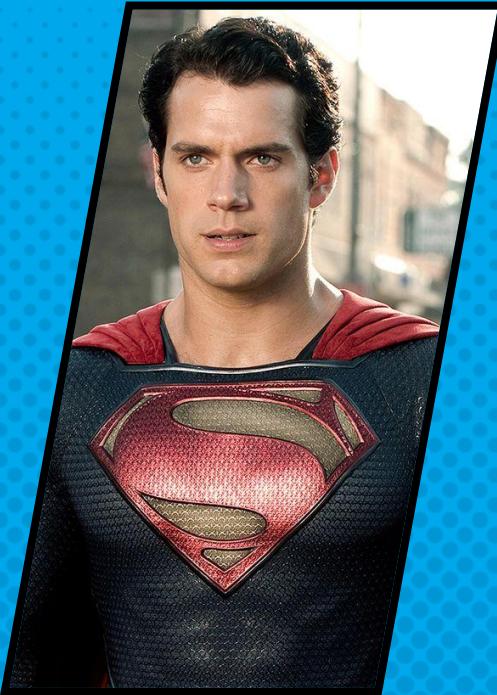


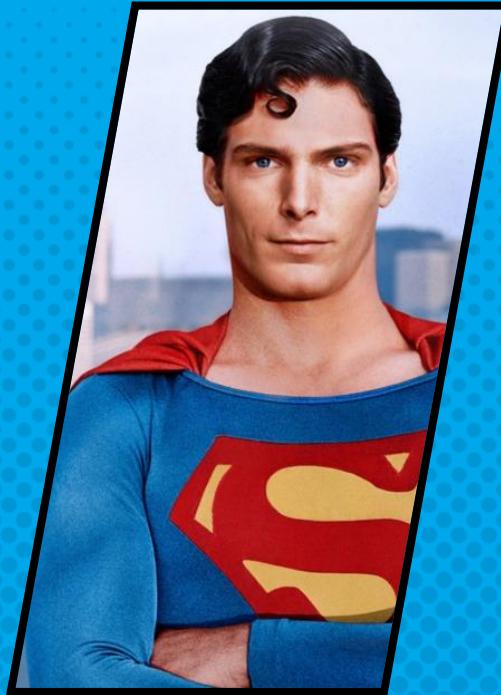
TCP



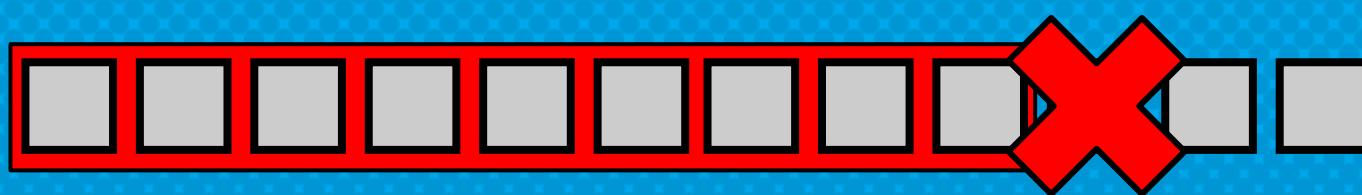


TCP

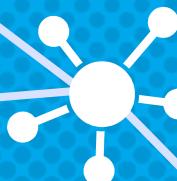


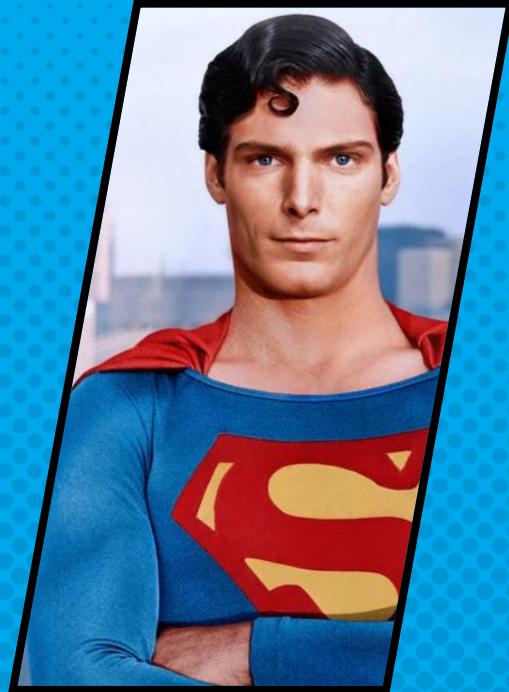


TCP

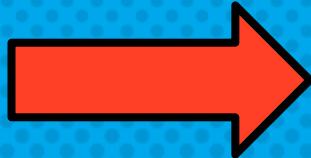








TCP



UDP 



HTTP/2



TLS 1.3



TCP

QUIC

IP



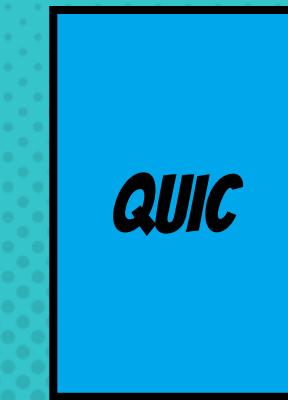
HTTP/2



TLS 1.3



TCP



HTTP/2 OVER QUIC



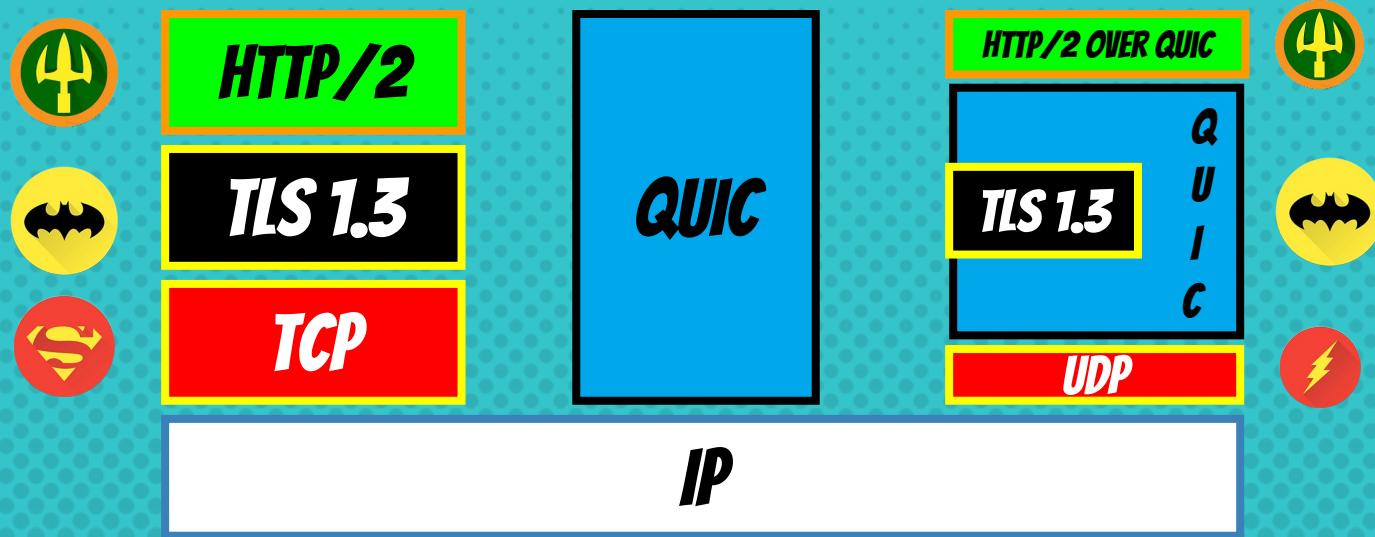
TLS 1.3

**Q
U
I
C**

UDP



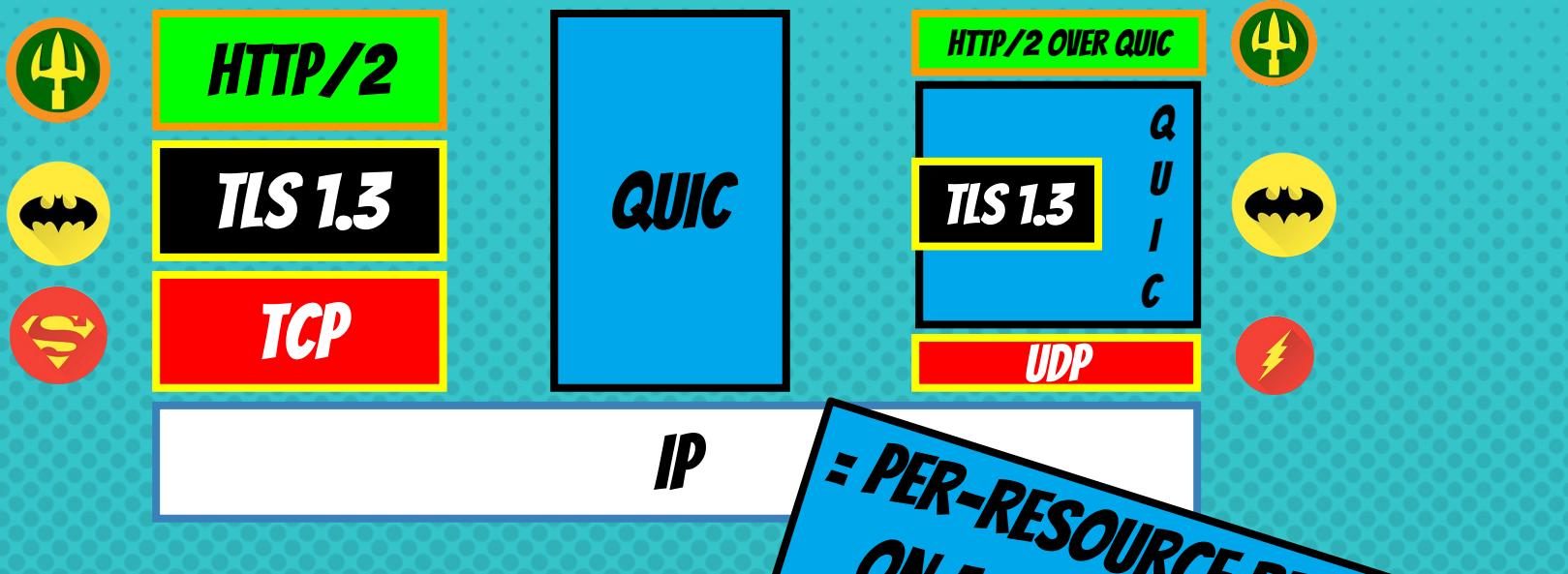
IP



QUIC

- Steals Multiplexing from HTTP/2
- Re-implements In-order Reliability on top of UDP





QUIC

- Steals Multiplexing from HTTP/2
- Re-implements In-order Reliability on top of UDP

THE MOTHER OF ALL PROTOCOLS

1. ++Security
2. Prevent middlebox meddling through encryption
3. ConnectionID and Multipath
4. Forward Error Correction, Header compression,





CUSTOM CONGESTION CONTROL





***CUSTOM
CONGESTION
CONTROL
+ NETINFO API***

wicg.github.io/netinfo



WE
DON'T KNOW



gQUIC



>7% of global traffic

Battle-tested (but
only by Google)

gQUIC



>7% of global traffic

Battle-tested (but
only by Google)

iQUIC

0% of global traffic

14 implementations

Not integrated into browser

V1 POC by end of 2018

<https://github.com/rmarx/quicker>

<https://github.com/quicwg/base-drafts/wiki/Implementations>



Latency reduction



8% ON DESKTOP

On average

3.6% ON MOBILE

On average

Latency reduction



8% ON DESKTOP

On average

3.6% ON MOBILE

On average

76 - 14%

99th percentile

0-RTT success rate



88% ON DESKTOP

68% ON MOBILE



QUIC is better than TCP, HTTP/2 (and 1.1) (on lossy networks)



20% less rebuffering for YouTube in India

14% faster than TCP (H1.1 and H2) on 4G

20% slower with loss vs TCP H1.1 100% and H2 >200%

Langley et al., *The QUIC Transport Protocol: Design and Internet-Scale Deployment*, 2017
Cook et al., *QUIC: Better for What and for Whom?*, 2017
Megyesi et al., *How quick is QUIC?*, 2016

Is QUIC really better than TCP, HTTP/2 (and 1.1) ?



Up to **75%** less Mbps than TCP for DASH streaming

100% slower than TCP if packet re-ordering

30% slower than TCP H1.1 on fast lossy network

Bhat et al., *Not so QUIC: A Performance Study of DASH over QUIC*, 2017

Kakhki et al., *Taking a Long Look at QUIC*, 2017

Carlucci et al., *HTTP over UDP: an Experimental Investigation of QUIC*, 2015

Userspace
overhead

QUIC COSTS

$\approx 2X$ CPU

COMPARED TO TCP/TLS

Userspace
overhead

58% OF TIME

CPU, NOT NETWORK

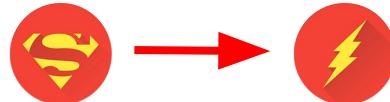
WAS SLOWDOWN CAUSE

ON MOBILE



QUIC: THE MOTHER OF ALL PROTOCOLS

1. TCP → UDP



2. Security, performance and evolvability

3. Better overall, but especially for lossy networks

PREDICTING THE FUTURE



1. Move to HTTP/2 (or at least HTTPS)
2. Just flip the switch™ (2019-2020)
3. Prepare to use tweak-tools (push + congestion control)



IMAGE SOURCES

<https://www.slidescarnival.com/jachimo-free-presentation-template/1393>
<https://www.dafont.com/justice-league.font?text=Combined>
<https://thegothamguardian.deviantart.com/art/DCEU-Aquaman-Logo-647002738>
<https://adeadhitya.deviantart.com/art/Superman-Batman-Wonder-Woman-Aquaman-06-476438059>
<http://bitsup.blogspot.be/2017/04/on-merits-of-quic-for-http.html>
<https://iconscout.com/icon-pack/superhero>
<https://www.pinterest.com/pin/560698222343595129/>
[http://batman.wikia.com/wiki/Batman_\(Dozierverse\)](http://batman.wikia.com/wiki/Batman_(Dozierverse))
<https://comicvine.gamespot.com/forums/battles-7/superman-reeves-vs-dceu-trinity-1883176/>
<https://sirawesomelyodd.deviantart.com/art/Whale-Tail-312314009>
<https://i.pinimg.com/originals/03/9d/82/039d82709d5ddbd3e7d0111b1c3fcc22.jpg>
<http://weknowmemes.com/2013/07/aquamans-worst-enemy/>
http://friendshipismagicfanon.wikia.com/wiki/File:Portal_outer_v2.png
http://dc.wikia.com/wiki/Aquaman_Recommended_Reading
<http://www.weirdsciencedccomics.com/2017/09/aquaman-28-review-and-spoilers.html>
<http://www.stickpng.com/img/objects/toys/lego-batman>
<https://letterboxd.com/film/the-dark-knight/>
<http://www.adam-williams.net/biography/a-treasure-from-the-vault/>
<https://www.flickr.com/photos/davegray/147874576>
<https://www.polygon.com/2017/7/24/16021098/superman-mustache-justice-league-reshoots>
<https://www.youtube.com/watch?v=VuolS1XU4Wc>
<https://imgflip.com/mememplate/27729883/Batman-thumbs-up>
<https://imgur.com/gallery/ZCMeDZb>
<https://imgflip.com/mememplate/74873042/Batman-Surprised>
<https://warosu.org/tg/image/t22R8ffvDgOvANPEzOLDXg>
<https://www.pinterest.com/pin/172755335686810350/>
<https://batman-news.com/2016/01/08/jesse-eisenberg-lex-luthor-going-bald-is-the-greatest-scene-ive-ever-done/>