The Lightning Network

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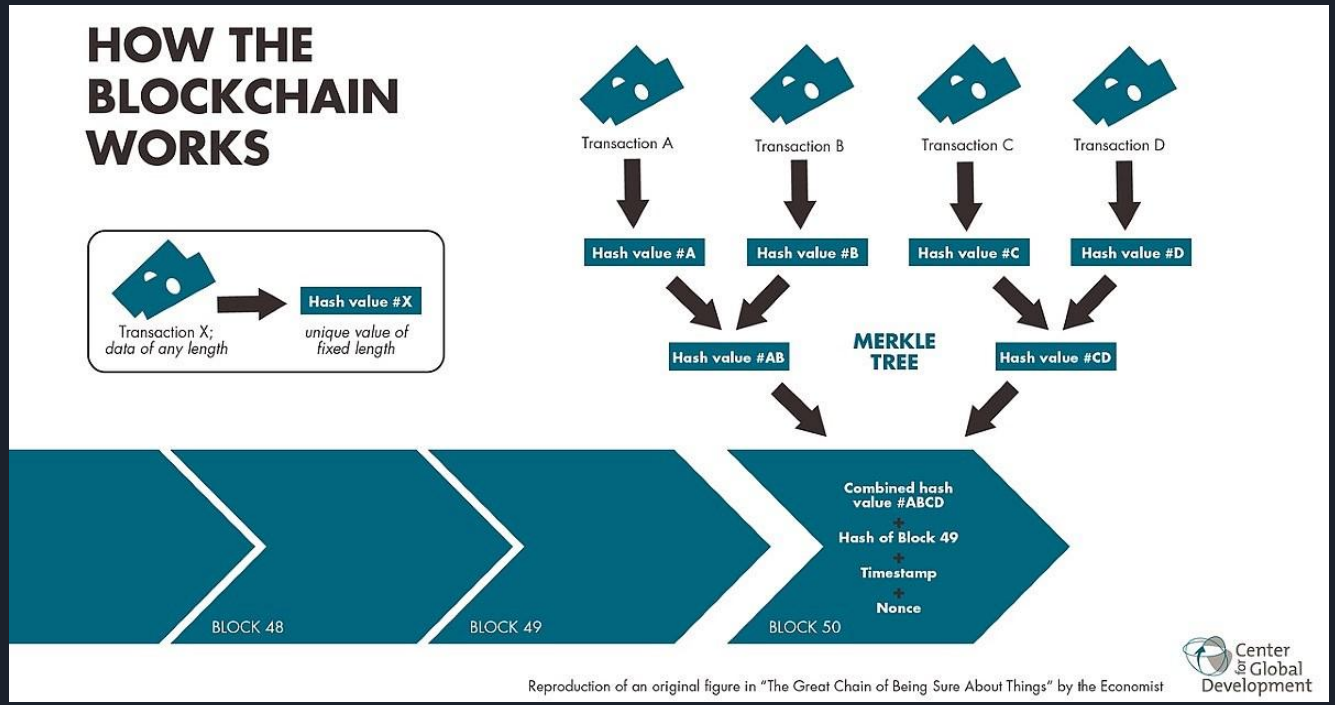
What is Bitcoin?

- Currency created in 2009 by Satoshi Nakamoto (pseudonym)
- Peer-to-peer transactions designed to eliminate the need for a financial institution
- 1 Bitcoin = 9440.09 Canadian dollars

What is Blockchain?

- Continuously growing list of records, known as blocks
- Blocks are linked securely using cryptography



Bitcoin Scalability Problem

- 1mb block size limit
- Time to create new blocks
- Maximum number of transactions per second
- The Solution: The Lightning Network

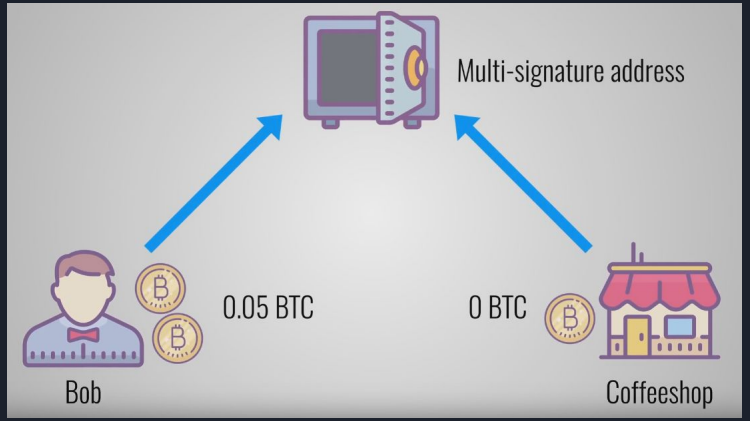
What is the Lightning Network (LN) ?

- Proposed by Joseph Poon & Thaddeus Dryja
  - https://lightning.network/lightning-network-paper.pdf
- Specifications for a payment channel on top of the bitcoin blockchain
- “Layer 2” solution to the Bitcoin scalability problem
- Decentralized, High Volume, Instant Micropayment

How does it work?

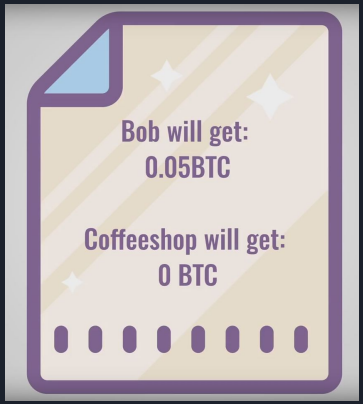
Set up a payment channel

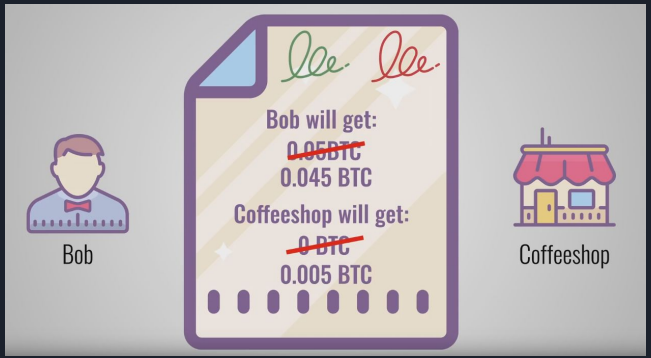
Both Bob and the Coffee Shop deposit bitcoin into a Multi-signature address

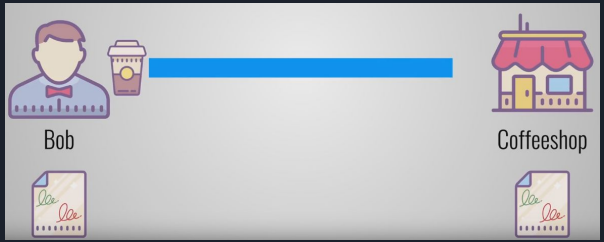


Reference: Simply Explained - Savjee (Youtube)

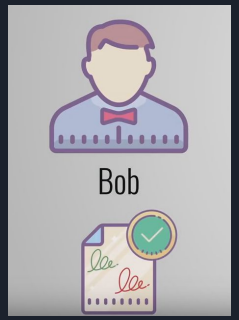
How does it work?

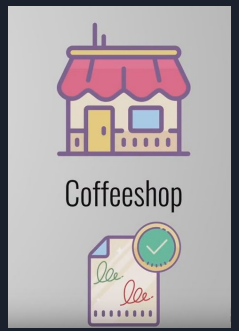




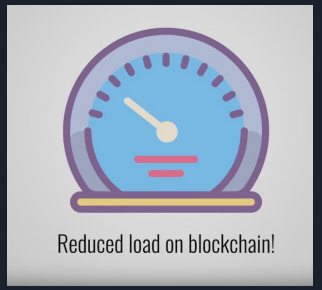


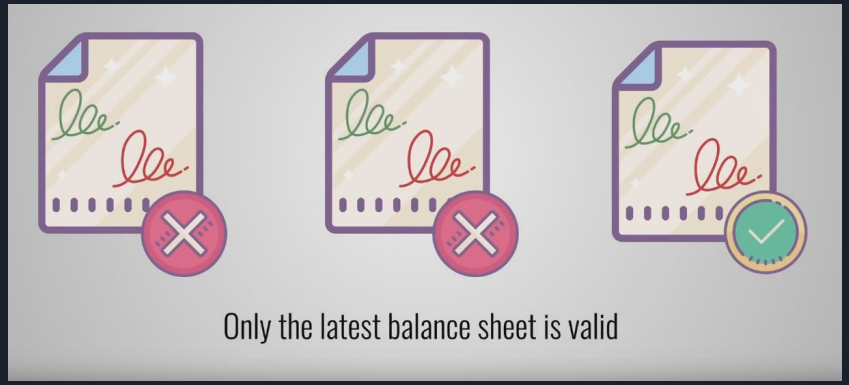
How does it work?



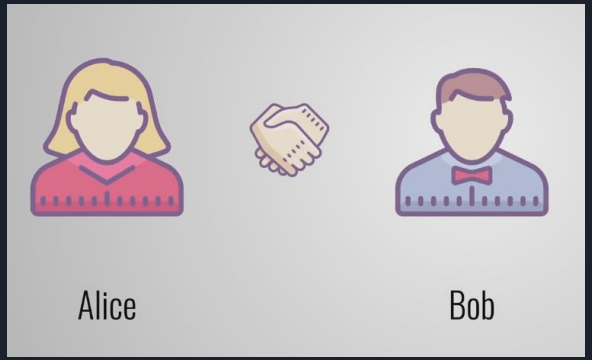


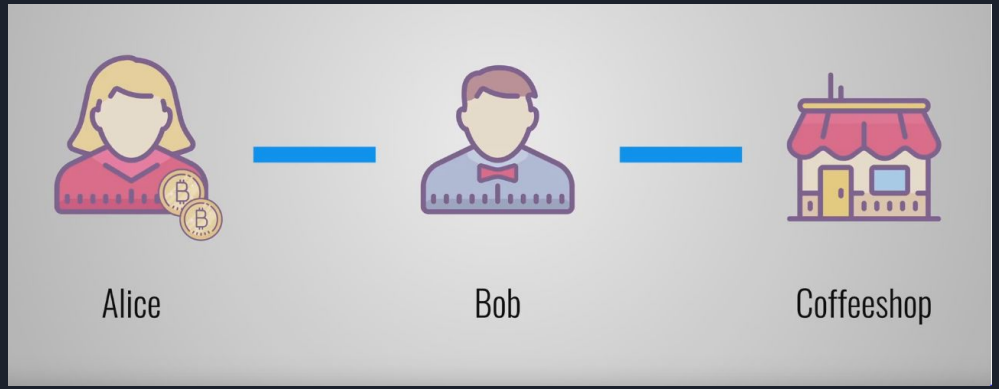
How does it work?

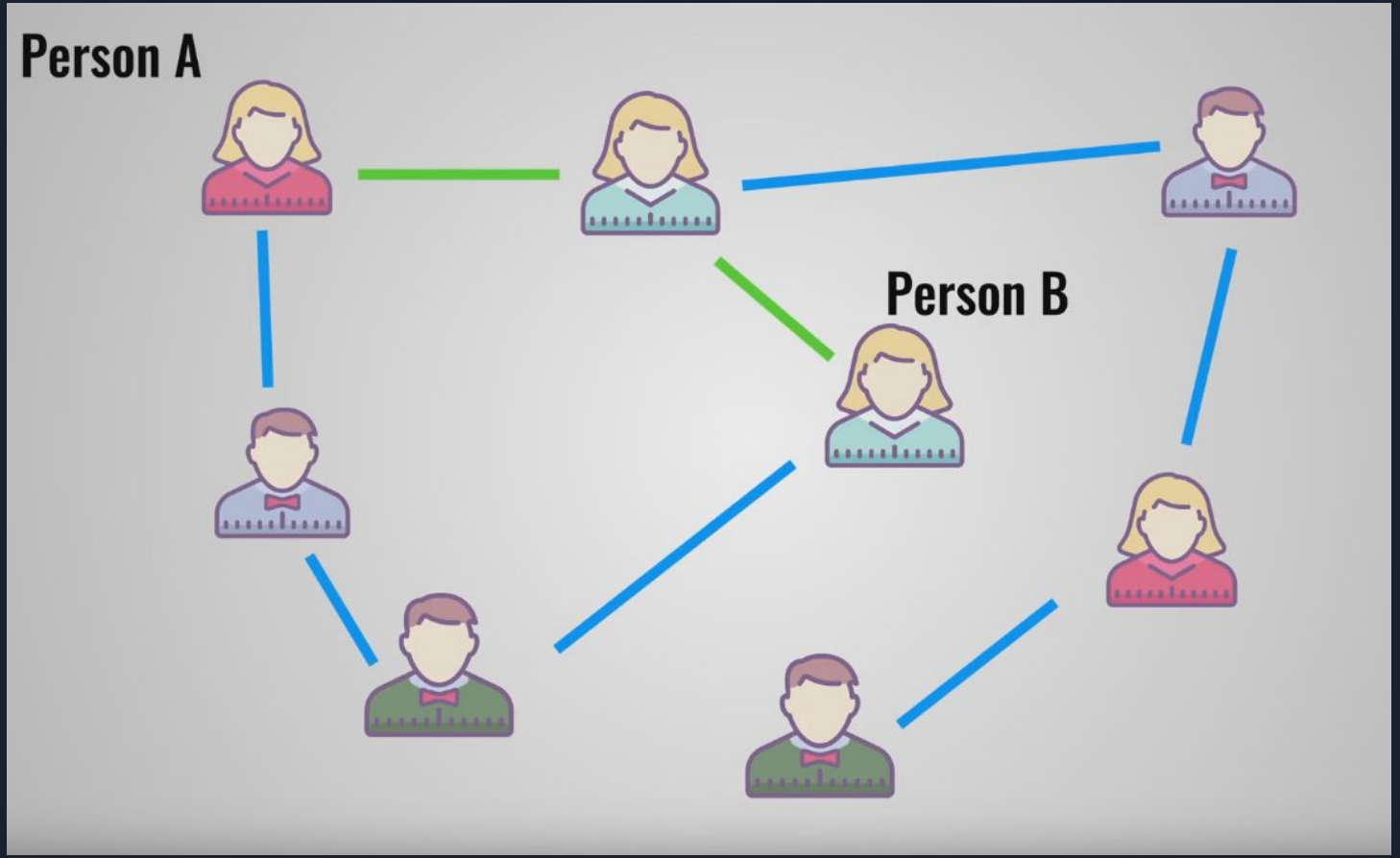




How does it work?

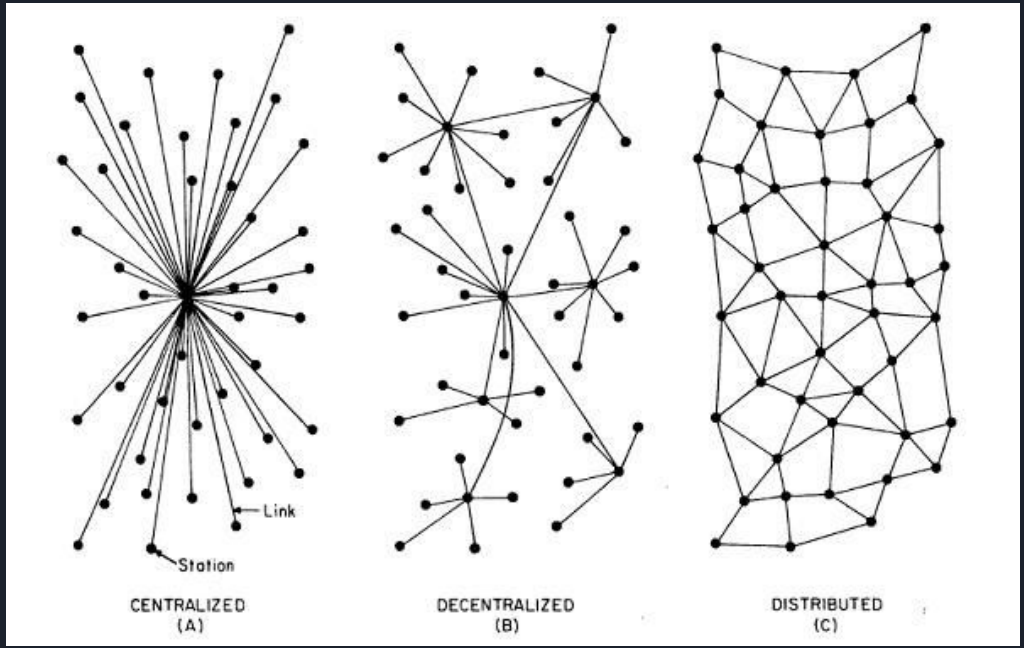





Person A
Person B

Difference between “Centralized”, “Decentralized” and “Distributed” network

- Centralized: One node does everything
  - i.e. bank system
- Decentralized: have multiple “hubs” connecting to multiple nodes.
  - i.e. Lightning network
- Distributed: nodes are only connected to peers, no hubs or central node.
  - i.e. peer 2 peer projects (blockchain)



Raw Data

- https://shabang.io/
- Updates every 15 min
- Our data was collected March 19, 2018 at 4:38 PM.
- Original data file downloaded: nodes.json , channels.json, stats.json
  - nodes.json : source, destination, short_channel_id, flag, active, public, last_update, base_fee_millsatoshi, fee_per_millionth, delay
  - channels.json: nodeid, alias, color, last_timestamp, addresses, port
  - stats.json: height, lightning_node, lightning_channel, segwit_input, total_input, lightning_channels_funded
- 843 nodes , 4779 channels, 514312 blockheight (at the time the data was collected)

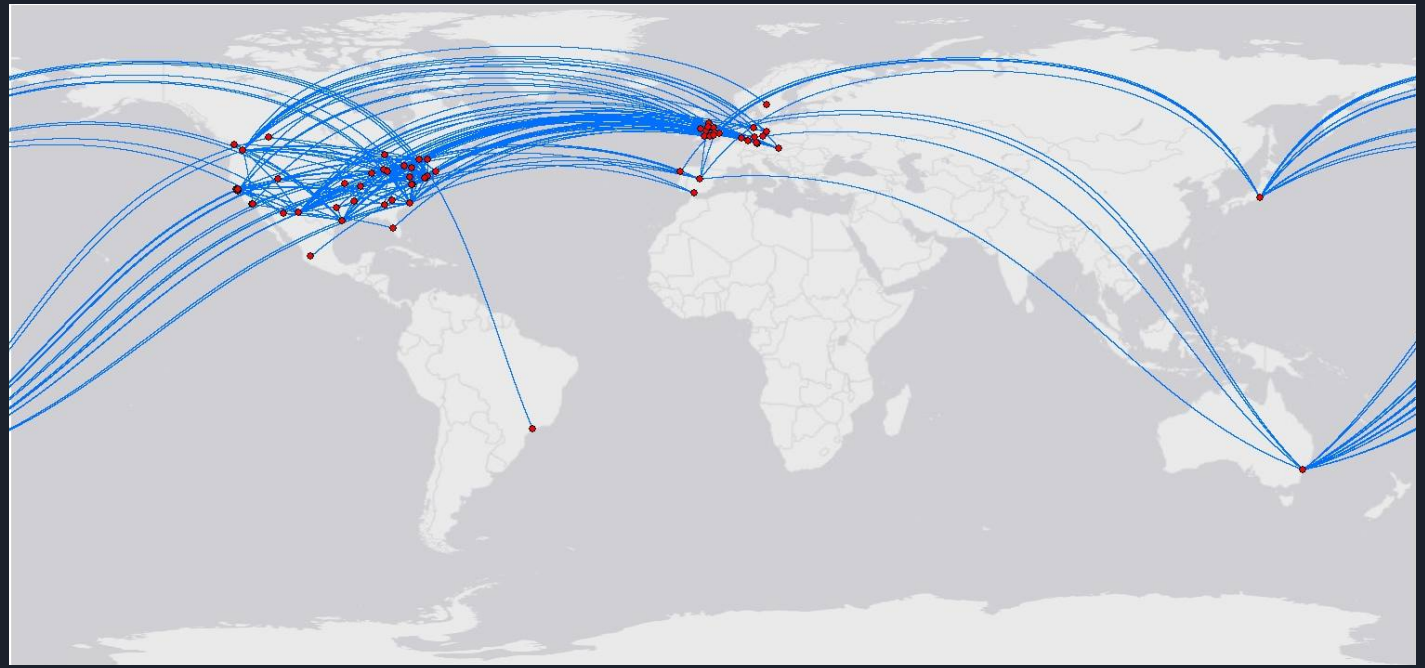
Data cleaning

- Convert all 3 files from .json into .csv files
- Discard stat.csv (not used for our project)
- Reducing 843 nodes into 381 nodes
  - Subsetting the nodes data with proper IP address (removing data with unknown IP addresses)
  - Eliminating all missing data and encrypted data
- Geo-locate each of the nodeid
  - Converting IP addresses into continent, country, region, city, longitude and latitude coordinates
- Reformat the data column names and combine based on the nodeid, source and nodeid, target
  - nodes.csv: source, target, weight (base fee in mill-satoshi)
  - edges.csv: nodeid, alias, latitude, longitude

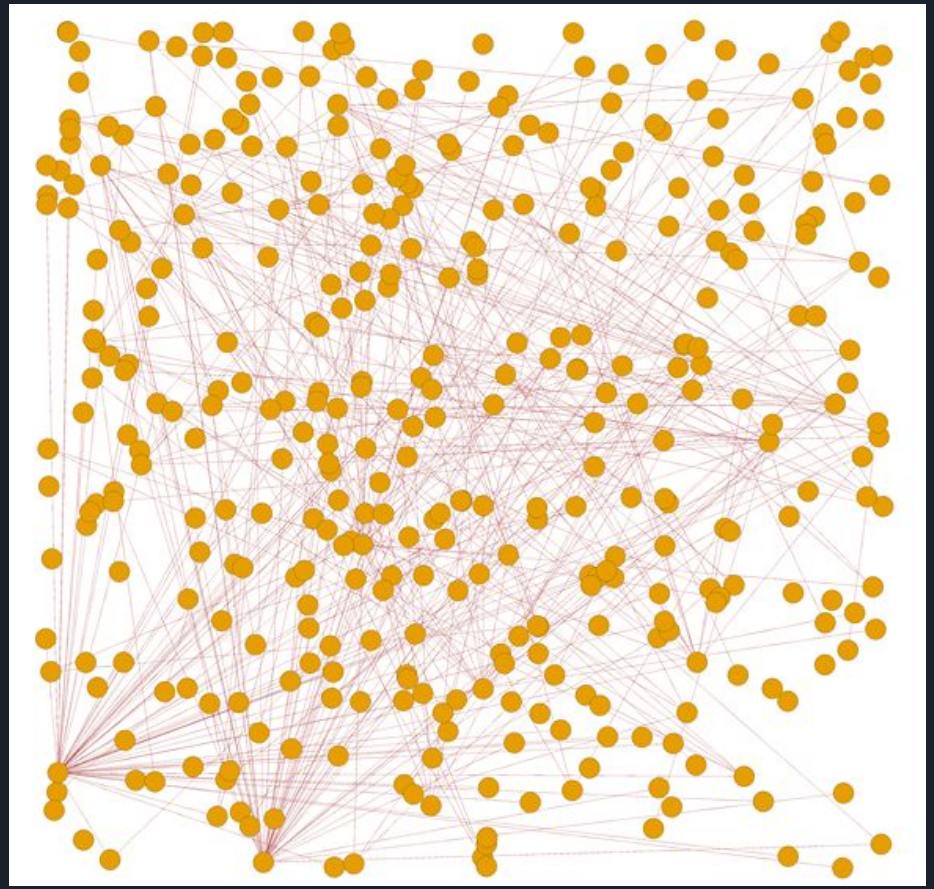
```
> head(nodes)
                                                                nodeid            alias  color last_timestamp addresses.0.type addresses.0.address addresses.0.port addresses.1.type addresses.1.address addresses.1.port
1 03b7d8b6bbaf02239277ed32378d50d29840292b61d516d30057b74044992c93dd          ALIBABA 0066cc     1518572211            ipv4     173.212.218.204            9735                                                    NA
2 0330c464cb2be97cd4ca5057b192a2be3c775a5f0356aced805769cb8790b879c0  Nick's LND Node 551a8b     1521501156            ipv4          51.6.89.26            9735                                                    NA
3 03b3b683a829e3ba10c68b9952fc348460f991735859b93deac3acc2dbcbe412fe        neowisard 03b3b6     1520973153                                                NA                                                    NA
4 032a16a13ffc9cb7c2e06d99d3c0d57cb140426d1ce80084afd2bef6078fd5c72a    STRANGEWHISPER 032a16     1516675975                                                NA                                                    NA
5 03e3d670d86f33181ee7451f14998b376a0d5deba8ab064b4ebe5ad5706f7b112b CN_Pek_HappyHome ff0000     1518465126            ipv4      222.129.253.32            9735                                                    NA
6 023daf469bbf2d5769d7673b66a841bd6d46452a4e20be548c6b11da730e5db575       SILENTROUTE 023daf     1520645230            ipv4       193.224.22.11            9735                                                    NA
> head(channels)
                                                                source                                                         destination short_channel_id flags active public last_update base_fee_millisatoshi fee_per_millionth delay
1 03b7d8b6bbaf02239277ed32378d50d29840292b61d516d30057b74044992c93dd 020d3d5995a973c878e3f6e5f59da54078304c537f981d7dcef73367ecbea0e90e     509070:571:0     1  false   true 1518717986                1000               10    14
2 0330c464cb2be97cd4ca5057b192a2be3c775a5f0356aced805769cb8790b879c0 02ad411014bb942951d30cef65c6e99aa66f05fd383d25748f78782f07f32f8fb2     514269:320:1     1  false  false         NA                  NA               NA    NA
3 0330c464cb2be97cd4ca5057b192a2be3c775a5f0356aced805769cb8790b879c0 0207481a19a3f51a48f134e95afa67cfeffdb38a99b5ad3494a320c4918aaaf579     514306:1709:0     1   true   true 1521500944                1000                1   144
4 0330c464cb2be97cd4ca5057b192a2be3c775a5f0356aced805769cb8790b879c0 027ccec61f4bf1fafb5156931da6527dc104ec3613dd4f4050161d89dd76ab494c      514307:84:1     1   true   true 1521500548                1000                1   144
5 03b3b683a829e3ba10c68b9952fc348460f991735859b93deac3acc2dbcbe412fe 02f6725f9c1c40333b67faea92fd211c183050f28df32cac3f9d69685fe9665432     512239:1154:1     1   true   true 1520972998                1000               10    14
6 03b3b683a829e3ba10c68b9952fc348460f991735859b93deac3acc2dbcbe412fe 0371190acfb2e92bd1faa6ce4d12ff248798515a92ac903ac14d31b5172d9b2917     512256:1573:0     1   true   true 1520972997                1000               10    14
```

Lightning Network - World Map (ArcMap)

- Asia (9 nodes), Europe (48 nodes), North America (323 nodes), South America (1 node)
- 307 nodes are in United States of America
  - Michigan has the most nodes, with its city Ann Arbor having 102 nodes

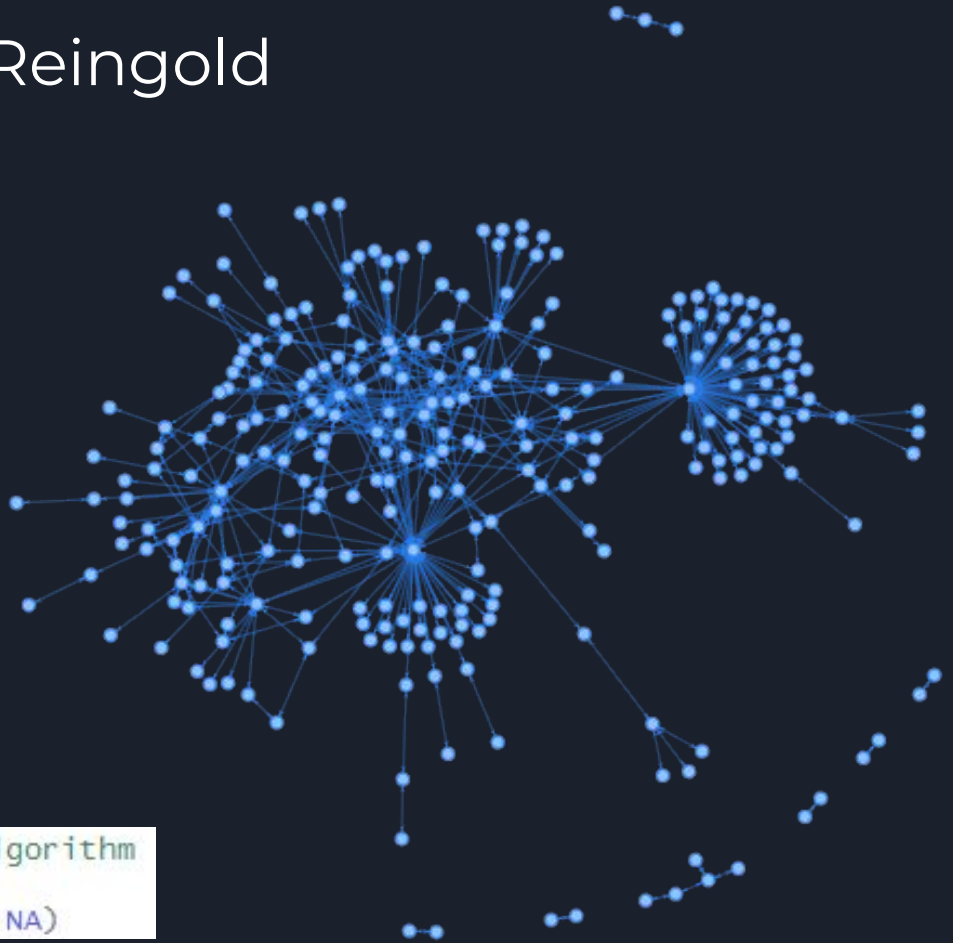


Simple Graph



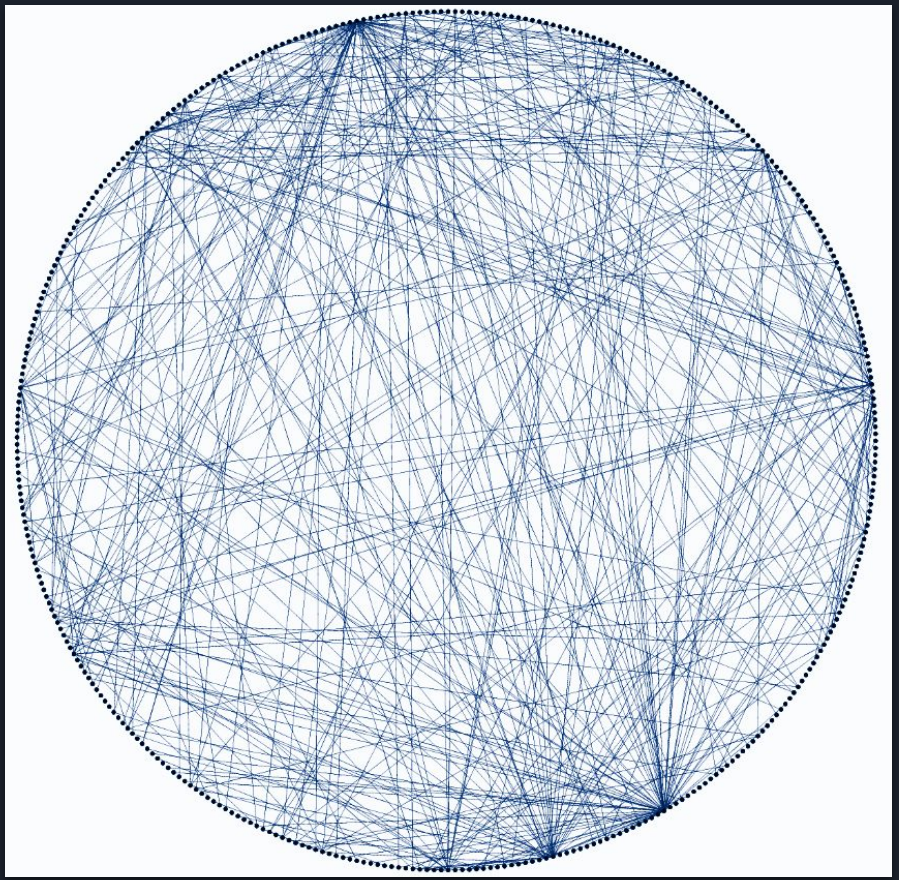
```
plot(net, layout = layout_randomly, vertex.label = NA, vertex.size = 5, edge.lty = 1,
     edge.color = "brown", axes = TRUE, edge.arrow.mode = 0, frame = TRUE, main = "Simple graph")
```

Fruchterman-Reingold



```
#Plotting with Fruchterman-Reingold algorithm
l3 <- layout_with_fr(net)
plot(net, layout = l3, vertex.label = NA)
```

Circle Graph



```
l <- layout_in_circle(net)
plot(net, layout = l, vertex.size = 1, edge.lty = 1, edge.color = "brown",
     vertex.color = "blue", axes = TRUE, edge.arrow.mode = 0, frame = TRUE,
     main = "Circle Graph", vertex.label = NA)
```

Degree of a vertex

```
degree(netGraph, v = V(netGraph), mode = c( "all"), loops = FALSE, normalized = FALSE)
```

03b7d8b6bbaf02239277ed32378d50d29840292b61d516d30057b74044992c93dd2	0330c464cb2be97cd4ca5057b192a2be3c775a5f0356aced805769cb8790b879c00
0267db6fbe76e1fbae50e27529a330837e9e1f4b9e4c7bbfefd7d6a1b3ffe2b2450	026b4f8931fcf87033d0f601ad7e4baa8e93ee74acf313292fd397fd6c275241624
03efeea8961f376931a390ed9ae62be116abc1a8abaad6d1998efcc11d63e865268	0207197d1028b8a7edfee28f4e2dc47905333b2c4f9ed40bcd2c7481abe8fb049a8
0235447c7485ff2b945bac5fbc366d54a87389bab8cacf1b64b26ec01e96bd165a26	0323e18348bb2afc29660da8ba06fb1e91fc37a5752301180b8f3afca7f5c49f010
02c119d2fd2e98a88f50d0d2ee4213255b7b8ec2be3a95f9aabd6afb09dd25b08338	03587e75c5928c0bdaae3b100f3edf7211bfd900d08a93f391e7d20fe062eeb37c2
0208b6ec8c4c77cabef8351f92327c13e0b7cc2e3724083669de305e2b395341fe0	0226b317ebf63a888838c2900b0e77e45b3ad35c59bdbbd6a8eaba0c0362303cee0
033ac2f9f7ff643c235cc247c521663924aff73b26b38118a6c6821460afcde1b38	02b7060f74b7e04d3d8af97fab20381fcc16f7a33c7e526fa5c9b96afdb288d7d210
02a90ee457ad397e5e882780b1fa0d109c3b66479d38e7682f5ee75fe995800f8e2	03cea3557a68bb4f2845808b937531e8666b16724e1d5f24215d9234efc5a57e7d2
0355cf9ce813a343313e1a4844f82c34810619943cb193cbfbead08da15d80fb980	0392e78c508987c97de70b2474493e9b0dbbd0dcad69dec2648d686701da1df44a2

Top 3 Results:

020d3d5995a973c878e3f6e5f59da54078304c537f981d7dcef73367ecbea0e90e	128
02f6725f9c1c40333b67faea92fd211c183050f28df32cac3f9d69685fe9665432	100
021f2cbffc4045ca2d70678ecf8ed75e488290874c9da38074f6d378248337062b	54

Global Clustering coefficient

$$C = \frac{3 \times \text{number of triangles}}{\text{number of connected triplets of vertices}} = \frac{\text{number of closed triplets}}{\text{number of connected triplets of vertices}}.$$

```
> # Clustering coefficient (transitivity of a graph)
> transitivity(netGraph, type = ( "global"), vids = V(netGraph),
+              weights = E(netGraph)$weight, isolates = c("NaN", "zero"))
[1] 0.02839833
```

Betweenness Centrality

$$g(v) = \sum_{s \neq v \neq t} \frac{\sigma_{st}(v)}{\sigma_{st}}$$

```
#Betweenness calculation
betweenness(netGraph, v = V(netGraph), directed = TRUE, weights = E(netGraph)$weight,
            nobigint = TRUE, normalized = FALSE)
```

03b7d8b6bbaf02239277ed32378d50d29840292b61d516d30057b74044992c93dd	0330c464cb2be97cd4ca5057b192a2be3c775a5f0356aced805769cb8790b879c0
0.00000	0.00000
0267db6fbe76e1fbae50e27529a330837e9e1f4b9e4c7bbfefd7d6a1b3ffe2b245	026b4f8931fcf87033d0f601ad7e4baa8e93ee74acf313292fd397fd6c27524162
0.00000	6.50000
03efeea8961f376931a390ed9ae62be116abc1a8abaad6d1998efcc11d63e86526	0207197d1028b8a7edfee28f4e2dc47905333b2c4f9ed40bcd2c7481abe8fb049a
1311.23177	604.26638
0235447c7485ff2b945bac5fbc366d54a87389bab8cacf1b64b26ec01e96bd165a	0323e18348bb2afc29660da8ba06fb1e91fc37a5752301180b8f3afca7f5c49f01
8011.68002	0.00000
02c119d2fd2e98a88f50d0d2ee4213255b7b8ec2be3a95f9aabd6afb09dd25b083	03587e75c5928c0bdaae3b100f3edf7211bfd900d08a93f391e7d20fe062eeb37c
4652.37868	0.00000
0208b6ec8c4c77cabef8351f92327c13e0b7cc2e3724083669de305e2b395341fe	0226b317ebf63a888838c2900b0e77e45b3ad35c59bdbbd6a8eaba0c0362303cee
0.00000	0.00000
033ac2f9f7ff643c235cc247c521663924aff73b26b38118a6c6821460afcde1b3	02b7060f74b7e04d3d8af97fab20381fcc16f7a33c7e526fa5c9b96afdb288d7d2
280.40898	112.66667
02a90ee457ad397e5e882780b1fa0d109c3b66479d38e7682f5ee75fe995800f8e	03cea3557a68bb4f2845808b937531e8666b16724e1d5f24215d9234efc5a57e7d
0.00000	0.00000
0355cf9ce813a343313e1a4844f82c34810619943cb193cbfbead08da15d80fb98	0392e78c508987c97de70b2474493e9b0dbbd0dcad69dec2648d686701da1df44a
0.00000	0.00000
0325fd957aeaead3635d7593b56c717090f95e7808290216b452e23fb2c0d77d11	02a0f1e7defe594d4f89e056ac45dbc3c2bdb29480270ed11c11040128a4ca6285
0.00000	91.66667
0388157a19ed80015b64bf9cd3cbc3c3c4492822341ab7813c7f9c0dbccc08fb26	035ec1f8ea7d376385dfa7c92bd9a0c43e1c88a4058179c3a80ac68abc27dd2389
0.00000	0.00000

Betweenness Centrality

Top 3 Results:

020d3d5995a973c878e3f6e5f59da54078304c537f981d7dcef73367ecbea0e90e	27161.08
02f6725f9c1c40333b67faea92fd211c183050f28df32cac3f9d69685fe9665432	21528.95
021f2cbffc4045ca2d70678ecf8ed75e488290874c9da38074f6d378248337062b	10327.28

Edge-Betweenness

```
#Edge-Betweenness calculation
edge_betweenness(netGraph, e = E(netGraph),
directed = TRUE, weights =  E(netGraph)$weight)
```

$$c_B(e) = \sum_{s,t \in V} \frac{\sigma(s,t|e)}{\sigma(s,t)}$$

```
  [1]  255.00000  244.50000   17.00000  697.37519  295.68911  478.69884   94.46862  115.01568  355.10399  191.71221  197.43450
 [12]  255.00000  237.62882  209.47108  693.75833  195.65514  104.85244  391.50878  341.19506  285.45280  665.60403  743.75000
 [23] 3769.18569  373.61784  134.53611  240.88957  260.01449   86.17338  227.20390  169.88922  481.30000  212.56739  255.00000
 [34]  118.10609  653.54573  255.00000  178.01268  255.00000  255.00000  441.96139  197.12019  231.05855  255.00000  255.00000
 [45]   86.02857  165.82118  110.30992  173.24931   14.50000  171.00000   70.00000   74.00000   38.16667  255.00000  255.00000
 [56]    1.00000  259.63810   87.02857  255.00000  173.69299  219.76997    1.00000  255.00000  255.00000 1025.82372 1052.50058
 [67]   91.96941  714.40924  255.00000  108.64591  255.00000  255.00000  319.53492   66.66190  255.00000  255.00000    1.00000
 [78]  255.00000 1040.17750   24.44136  145.10837 1223.13495  101.88501  255.00000  255.00000  277.00000  183.00000  616.82497
 [89]  147.24525  255.00000  255.00000   35.53096  255.00000   56.00000   68.67621   63.53096  115.76367   25.90000    7.00000
[100]  255.00000    7.00000  543.69701  255.00000   55.83096  255.00000  255.00000  255.00000  315.78333   80.18333  171.03889
```

Closeness Centrality

```
#Closeness centrality
closeness(netGraph, vids = V(netGraph), mode = ("total"),
                weights = E(netGraph)$weight, normalized = FALSE)
```

03b7d8b6bbaf02239277ed32378d50d29840292b61d516d30057b74044992c93dd	0330c464cb2be97cd4ca5057b192a2be3c775a5f0356aced805769cb8790b879c0
4.977259e-07	6.907031e-06
0267db6fbe76e1fbae50e27529a330837e9e1f4b9e4c7bbfefd7d6a1b3ffe2b245	026b4f8931fcf87033d0f601ad7e4baa8e93ee74acf313292fd397fd6c27524162
6.907031e-06	4.723398e-07
03efeea8961f376931a390ed9ae62be116abc1a8abaad6d1998efcc11d63e86526	0207197d1028b8a7edfee28f4e2dc47905333b2c4f9ed40bcd2c7481abe8fb049a
5.131284e-07	5.462723e-07
0235447c7485ff2b945bac5fbc366d54a87389bab8cacf1b64b26ec01e96bd165a	0323e18348bb2afc29660da8ba06fb1e91fc37a5752301180b8f3afca7f5c49f01
5.698132e-07	6.907031e-06
02c119d2fd2e98a88f50d0d2ee4213255b7b8ec2be3a95f9aabd6afb09dd25b083	03587e75c5928c0bdaae3b100f3edf7211bfd900d08a93f391e7d20fe062eeb37c
5.376570e-07	4.870453e-07
0208b6ec8c4c77cabef8351f92327c13e0b7cc2e3724083669de305e2b395341fe	0226b317ebf63a888838c2900b0e77e45b3ad35c59bdbbd6a8eaba0c0362303cee
6.907031e-06	6.907031e-06
033ac2f9f7ff643c235cc247c521663924aff73b26b38118a6c6821460afcde1b3	02b7060f74b7e04d3d8af97fab20381fcc16f7a33c7e526fa5c9b96afdb288d7d2
5.073278e-07	5.196995e-07
02a90ee457ad397e5e882780b1fa0d109c3b66479d38e7682f5ee75fe995800f8e	03cea3557a68bb4f2845808b937531e8666b16724e1d5f24215d9234efc5a57e7d
4.915853e-07	4.984451e-07
0355cf9ce813a343313e1a4844f82c34810619943cb193cbfbead08da15d80fb98	0392e78c508987c97de70b2474493e9b0dbbd0dcad69dec2648d686701da1df44a
6.907031e-06	6.877579e-06
0325fd957aeaead3635d7593b56c717090f95e7808290216b452e23fb2c0d77d11	02a0f1e7defe594d4f89e056ac45dbc3c2bdb29480270ed11c11040128a4ca6285
6.907031e-06	5.042318e-07
0388157a19ed80015b64bf9cd3cbc3c3c4492822341ab7813c7f9c0dbccc08fb26	035ec1f8ea7d376385dfa7c92bd9a0c43e1c88a4058179c3a80ac68abc27dd2389
4.977259e-07	6.907031e-06

Closeness Centrality

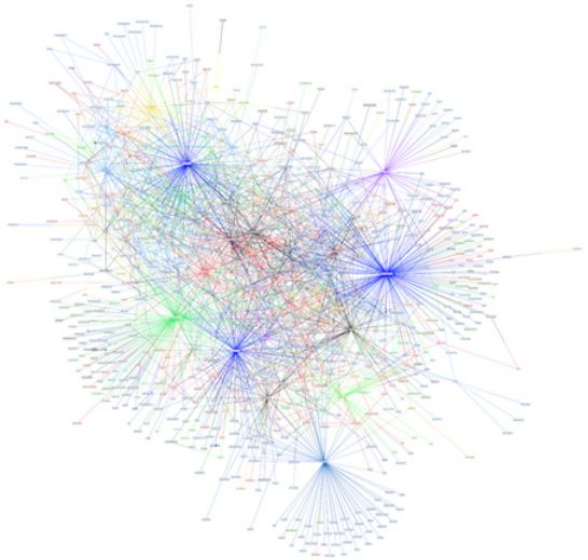
Top 3 Results:

0330c464cb2be97cd4ca5057b192a2be3c775a5f0356aced805769cb8790b879c0	6.91E-06
0267db6fbe76e1fbae50e27529a330837e9e1f4b9e4c7bbfefd7d6a1b3ffe2b245	6.91E-06
0323e18348bb2afc29660da8ba06fb1e91fc37a5752301180b8f3afca7f5c49f01	6.91E-06

Conclusion

Lightning Network DDoS Sends 20% of Nodes Down

March 21, 2018 12:17 pm



Lightning Network (LN) nodes faced a Distributed Denial of Service (DDoS) attack yesterday that sent offline around 200 nodes, down from around 1,050 to 870.

"Lightning nodes are getting DDOS'ed, rumor is that someone from the 2x effort known as "BitPico" has taken credit for this.