Networks of information token recurrences derived from genomic sequences may reveal hidden patterns in epidemic outbreaks: A case study of the 2019-nCoV coronavirus.

Markus Luczak-Roesch[1*]

1 Victoria University of Wellington, School of Information Management

*** markus.luczak-roesch@vuw.ac.nz**

Abstract

Profiling the genetic evolution and dynamic spreading of viruses is a crucial task when responding to epidemic outbreaks. We aim to devise novel ways to model, visualise and analyse the temporal dynamics of epidemic outbreaks in order to help researchers and other people involved in crisis response to make well-informed and targeted decisions about from which geographical locations and time periods more genetic samples may be required to fully understand the outbreak. Our approach relies on the application of Transcendental Information Cascades to a set of temporally ordered nucleotide sequences, and we apply it to real-world data that was collected during the currently ongoing outbreak of the novel 2019-nCoV coronavirus. We assess information-theoretic and network-theoretic measures that characterise the resulting complex network and identify touching points and temporal pathways that are candidates for deeper investigation by geneticists and epidemiologists.

Keywords: epidemic outbreaks, genome analysis, bioinformatics, complex systems, network analysis, sequential data mining

Introduction

How far a virus will eventually spread at local, regional, national and international levels is of central concern during an epidemic outbreak due to the severe consequences large-scale epidemics have on human well-being [5], the stability and coherence of social systems [11], and the global economy [23]. A thorough understanding of the genetic characteristics of a virus is crucial to understand the way it is (or may be) transmitted (e.g. human-to-human transmissibility) in order to be able to anticipate the potential reach of an outbreak and develop effective countermeasures. The recent outbreak of a new type of coronavirus – 2019-nCoV – provides plenty of examples of the way researchers seek to quickly approach the aforementioned problems of genetic decomposition of the virus [2, 8] and modelling of its transmission dynamics [15].

Here we present a novel approach to gain insights into the transmission dynamics of an epidemic outbreak. Our method is based on Transcendental Information Cascades [16,17] and combines gene sequence analysis with temporal data mining to uncover potential relationships between a virus' genetic evolution and distinct occurrences of infections. We apply this new approach to publicly available genomic sequence data from the currently ongoing outbreak of the 2019-nCoV coronavirus.

Our results show pathways of similarity between certain clusters of 2019-nCoV virus samples taken in different geographical locations, and indicate coronavirus cases that are candidates for further investigation into the human touch points of these patients in order to derive a detailed understanding of how the virus may have spread, and how and why it has genetically evolved. Our analysis provides a unique view to the dynamics of the 2019-nCoV coronavirus outbreak that complements knowledge obtained using other state-of-the-art methods such as Bayesian evolutionary analysis [9].

Materials and methods

Research data and preprocessing

We obtained a total of 87 genomic sequences from human subjects that were available via the *GISAID EpiFlu Database*™ [1] as of Monday, February 10th 2020.

These data were preprocessed using the R programming language. First, we derived a metadata object that allows to store the sequence identifier, the collection location, the collection date, and the raw nucleotide sequence. The metadata object was then filtered to keep only those sequences for which the collection date was not empty and which featured a length that fell within a margin of $1,000$ of the estimated $30,000$ nucleotides that are currently assumed to make up the genomic code of the 2019-nCoV coronavirus (i.e. we cover the range of nucleotide sequences from $29,000$ to $31,000$ in length). This left us with a total of 82 genomic sequences. We then exported a single CSV file containing only the raw nucleotide sequences in ascending order by the collection date of the sample. This structure is the standard input format for the *genes-CODON-samplesequence* tokeniser featured in the Transcendental Information Cascades R toolchain that is available as free and open scientific software[2].

Construction of Transcendental Information Cascades

Transcendental Information Cascades (TICs) are a method that first transforms any kind of sequential data into a network of recurring *information tokens*, to then exploit this network as a kind of analytical middle ground between views to the source data that would otherwise only be accessible individually through distinct analytical frameworks [16,17]. The approach falls into the category of contemporary approaches that make use of network theory for the study of dynamical complex systems [4,19,21]. In the field of phylogenetic and phylogeographic analysis our approach can be compared to haplotype networks for example [1,18] but with the benefit that the resulting network preserves access to temporal patterns at both macroscopic (e.g. whole generation time periods) and microscopic (e.g. short time period bursts) resolution.

At an abstract level a Transcendental Information Cascade is constructed from some sequentially ordered source data in the following way: At first the data from each distinct sequence step is processed to extract unique information tokens. These tokens form the *identifier set* for that particular sequence step. Then a directed network is generated with one vertex for each sequence step and edges between any two vertices that have a particular token from their identifier set in common and that does not occur in any identifier set of vertices that represent sequence steps between

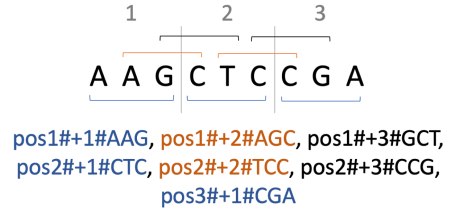


Figure 1. Example of the unique codon tokenisation used in this study. The example sequence comprises three window steps and shows how the +1 (marked in blue), +2 (marked in orange) and +3 (marked in black) reading frames lead to seven unique codon tokens extracted from the nucleotide sequence.

[1] https://www.gisaid.org/
[2] https://github.com/vuw-c2lab/transcendental-information-cascades

these two. In other words, identifier sets represent information token co-occurrences and edges represent information token recurrences.

As the information tokens of interest in this study we encode unique codon identifiers as (a) their position when sliding a window of size 3 in steps of size 3 over the nucleotide sequence (e.g. "pos1", "pos2", ...), (b) a flag that indicates the reading frame ("+1", "+2" or "+3") that captures the respective triplet in the current window, and (c) the actual matched nucleotide triplet that constitutes the matched codon. The use of this tokenisation is motivated by previous work on phylogenetic profiling and gene sequencing [6, 13] that suggested that codons suit well for assessing similarities (and dissimilarities) at the gene, chromosome, or genome levels [6, 14, 22].

An example of the particular encoding we use is visualised in Figure 1. It is this tokenisation of the original nucleotide sequences that we use in the TIC approach to construct the information token recurrence network from. This means in our TIC instantiation the nodes represent distinct nucleotide sequences of the virus obtained from patient samples ordered by the date of their collection by researchers (random order in case of same date collections). The edges are unique codon identifier recurrences matched between different nucleotide sequences.

Analysis of Transcendental Information Cascades

The TIC network we derive in the way described before can be analysed in a variety of ways. Information-theoretic and network-theoretic measures have been introduced as the base framework to start the analysis from [16]. In particular we perform (1) an analysis of the information token entropy and evenness over time, (2) an analysis of network clusters of sequences that can be detected in the TIC network, and (3) an analysis of the intra-cluster and inter-cluster nucleotide similarity of the original sequences.

Information token entropy and evenness We perform an analysis of information token entropy and information token evenness in order to understand whether the virus evolution can be considered an open or a closed system. Therefore we assess both measures in an accumulated fashion for each progression step through the ordered nucleotide sequences. In a closed system the information token entropy should strive towards an equilibrium of maximum entropy and not feature any wave-like up and down patterns. If we observe wave-like patterns it means nucleotide sequences at later progression stages feature codon identifiers that have not been observed in earlier nucleotide sequences.

So to measure information token entropy we assess which unique codon identifiers were seen up to a progression step and how often these were seen. This allows to compute the probability for every codon identifier, which then can be used to determine the information token entropy up to that point following the definition of Shannon entropy given as follows:

$$H' = -\sum_{i=1}^{R} p_i \ln p_i \tag{1}$$

Analog to this we can then assess the information token evenness as per Pielou's species evenness index, which is defined as

$$J' = \frac{H'}{H'_{\max}} \tag{2}$$

where H' is the measured Shannon entropy, and $H'_{\max}$ is the maximum entropy that would be measured if all tokens would be equally likely to occur.

Network analysis The Transcendental Information Cascade network we constructed can be mathematically and visually analysed in order to find structures that are of particular significance for a single epidemic outbreak or to compare different outbreaks structurally. In this study we focus on the former due to the lack of comparative data about other epidemic outbreaks.

We first perform a cluster analysis using the random walk apporach by Blondel et al. [3] on the weighted network that we can construct from our original TIC network by collapsing all edges between the same vertices to unique edges weighted by the sum of the collapsed edges (see Figure 2 for a schematic example and Figure 4 for the actual networks we construct following this approach). Afterwards, we analyse visually the network using the open source software Gephi. In Gephi we scale vertices by their degree and edges by their weight. Furthermore, we colour vertices by their cluster membership. We then run the *Yifan Hu* [12] layout algorithm (optimal distance: 10,000; relative strength: 0.2; initial step size: 20; step ratio: 0.95; quadtree max level: 50; theta: 0.8; convergence threshold: $1 * 10^{-4}$; adaptive cooling: enabled) to visualise the network. We repeat the exact same process to construct and visualise three further networks (cf. Figures 5-7) that are representative of the TIC when exclusively focusing on the codon identifiers of each of the reading frames individually.

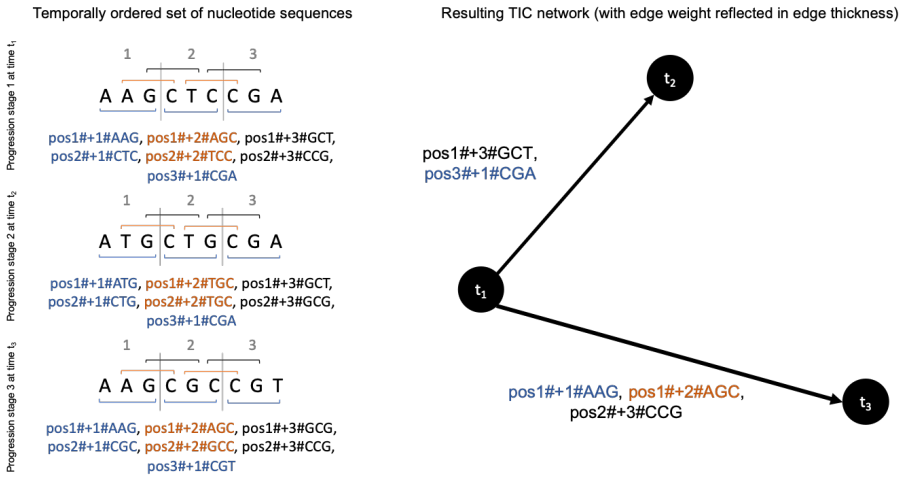


Figure 2. Schematic example of the weighted TIC network constructed from nucleotide sequences with tokenised unique codon identifiers.

Cluster evaluation In order to evaluate the meaningfulness of the TIC network against some baseline, we computer the intra-cluster and inter-cluster similarity of the raw nucleotide sequences. This is done by computing all pairwise comparisons of sequences within individual clusters (intra-cluster similarity) and comparison between all sequences from a cluster with all sequences that are not within that cluster (inter-cluster similarity) using the *compareStrings* function provided by the Biostrings R package [20]. The similarity of two sequences is then simply defined as follows:

$$sim(a,b) = 1 - \frac{number \quad of \quad different \quad nucleotides}{length \quad of \quad compared \quad nucleotide \quad sequence} \tag{3}$$

It is important to note that not all sequences we obtained had the exact same length (mean length of nucleotide sequences: 29861.95; standard deviation: 28.40705). Hence, we performed this comparison only on the sub-sequence from the first nucleotide position to the maximum nucleotide position of the shorter of the two sequences a and b.

Results and discussion

Information-theoretic analysis

Figure 3 shows the graphs for the information token entropy and information token evenness. As one can see, these feature the aforementioned wave-like patterns, which means the system can be regarded *open* in the sense that over time the number of unique codon identifiers grows.

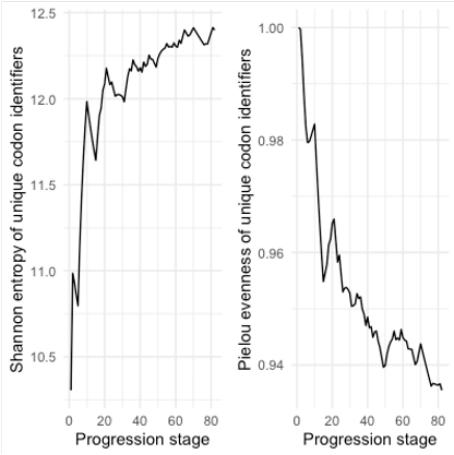


Figure 3. Information-theoretic assessment. Both entropy and evenness graphs feature wave-like patterns, indicating that the set of observed unique codon identifiers grows with increasing progression stages while the distribution of all observed unique codon identifiers remains rather even.

It is important to note that the evenness of the distribution of codon identifiers is relatively high, converging around a value of 0.95. This means that those codon identifiers that have been observed are quite evenly distributed.

These results allow the interpretation that (a) there is evolving variation in the genomic sequences we studied, but (b) there is no indication for the dominance of a particular variance.

Network analysis

The weighted network derived from the original TIC network features a modularity of 0.762 and a diameter of 7, which mainly reflects its small size and its particular structure that results from preserving temporal order in the sense that edges can only ever direct forward in time (i.e. to vertices that represent a later stage). However, with an average degree of 8.671 we find that there is certainly structure that differs from just simple step-by-step forward paths that lead to the consecutively next node. This latter result suggests that some codon paths branch and merge, emphasising that there is an evolving variation in the studied genomic sequences.

From the cluster analysis in combination with a visual inspection of the resulting graph (please refer to Figure 6 as well as Table 11 in the appendix) we find the following patterns that are noteworthy:

- At the center of the network one cluster emerges (dark red, cluster 0) that has only few stronger connections within the cluster but features connections to all other clusters and within itself through lower weighted edges. This cluster has no temporal focus, it comprises samples that were collected early as well as later during the outbreak. While the genome sequences that represent the beginning of the progression stage path in this cluster are from China, it then transitions geographically to Australia, Japan, Korea, Germany, Taiwan and Singapore.
- The light red cluster (cluster 1) comprises a coherent sequence of samples taken from patients in the original outbreak region (Wuhan) and is temporally focused on the early progression stages.
- The orange cluster starting from the bottom center of the network (cluster 2) is again first a sequence of samples from the original outbreak region in Wuhan, transitioning to Thailand (Nonthaburi), then back to China (Guangdong), before finishing in France.
- Cluster 3 (yellow) features samples taken in various places in China but also two later connections to the USA.

- Cluster 4 (light green) is one of the smallest clusters but is spread fairly wide temporally. It features 4 samples taken in China and then transitions geographically to Singapore and France.
- In dark green (cluster 5) we can identify a cluster of genome data that was collected in Chonggqing, the USA and Singapore.
- The light blue cluster (cluster 6) is a temporally quite coherent sequence that links samples taken in Guangdong, Guangzhou and Foshan.
- A kind of international cluster (samples from Australia, the USA, England, Finland and Belgium) is represented by the dark blue cluster (cluster 7).

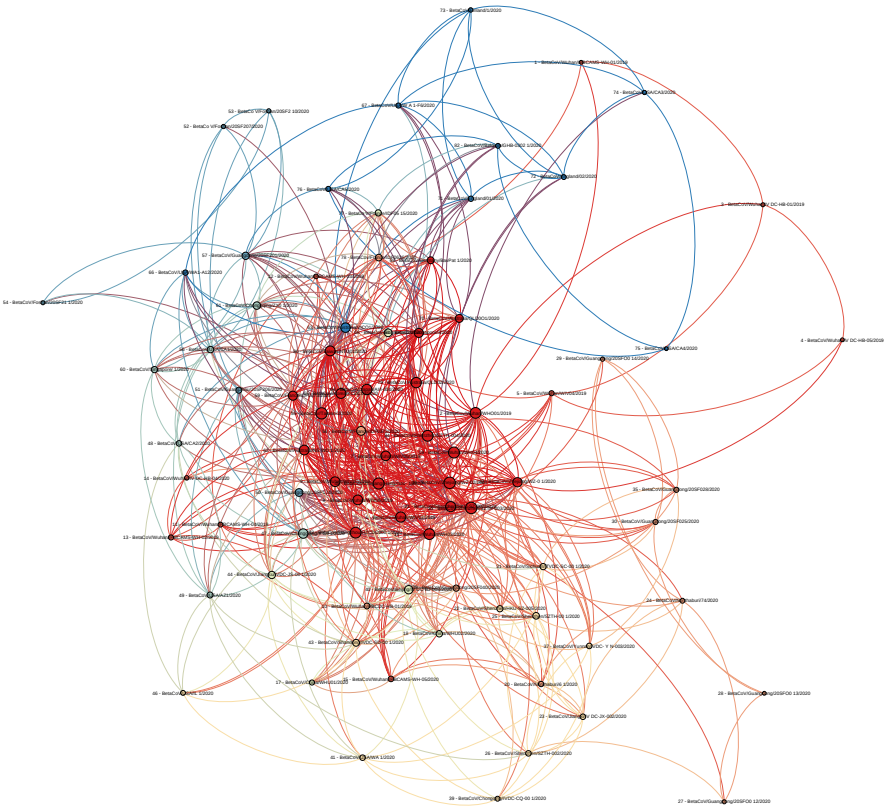


Figure 4. Figure 4. Weighted TIC network. From the original TIC network we generate a weighted network by collapsing all edges between the same vertices to unique edges weighted by the sum of the collapsed edges. The colours represent the nine identified network clusters. Node size represents the degree and edge thickness represents edge weight (in the sense that higher edge weight indicates a higher amount of codon identifiers shared by two vertices). Numeric indices before the genome identifiers represent the progression stage index of the particular vertex in the sequence of all ordered nucleotide sequences we analysed.

We suggest that while there are some obvious pathways of high similarity due to temporal order of the samples taken, there are still good indications for geographical-dependencies and transition phases that deserve further investigation. Transition points into and out of cluster 0 are particularly interesting in this regard, especially when the clusters linking in our out feature samples taken outside of China. We suggest that it

may be worth to qualitatively assess the human-to-human connections the respective subjects had from which these samples were taken, and the places they have visited if there are no known links between the samples so far.

Triangulating the full TIC network with the networks that focus on individual reading frame similarity only (please refer to Figures 6, 7 and 8 as well as Tables 13, 15 and 17 in the appendix) shows that the macroscopic structure is mostly consistent but much sparser in terms of low-weighted edges.

Inter- and intra-cluster similarity

From our measurement of the intra-cluster similarity (see Table 1) we find that the genomic similarity at the level of nucleotides is low in the central cluster 0, which is expected because this is the largest of all clusters with low temporal coherence. However, cluster 5 also features a slightly lower average similarity with comparably high standard deviation, which indicates that this cluster may be slightly less coherent.

Table 1. Intra-cluster similarities.

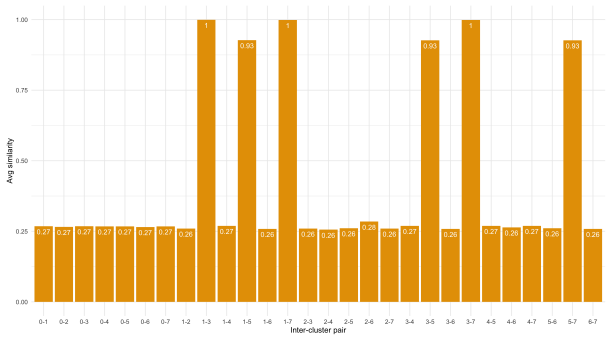
Cluster	Avg. similarity	SD	Min. similarity	Max. similarity	Cluster size
0	0.277353	0.088247	0.250620	0.999866	24
1	0.999730	0.000222	0.999231	1.000000	9
2	0.999915	0.000048	0.999832	1.000000	11
3	0.999385	0.000371	0.998461	0.999933	10
4	0.998768	0.001345	0.996387	1.000000	6
5	0.883701	0.112398	0.781976	0.999899	6
6	0.999926	0.000036	0.999866	1.000000	6
7	0.997900	0.002419	0.991158	1.000000	10

The barchart of the inter-cluster analysis results shown in Figure 5 reveals that there are some cluster pairs with high inter-cluster similarity, that the inter-cluster similarity is different between the +3 reading frame network and the other two reading frame networks, and that the pattern of the +3 reading frame network inter-cluster similarity is similar to the one for the entire TIC network. In particular we find that in the +1 and +2 reading frame networks the clusters 1, 4, 6 and 7 are quite similar at the nucleotide level compared to all other clusters that are pairwise distinct. For the entire TIC network and the +3 reading frame network instead we find that clusters 1, 3, 5 and 7 show this kind of similarity. Altogether, these results indicate that (a) in some instances the clustering based on structural characteristics of the TIC network overrides actual genomic similarity, and (b) the choice of the reading frames during TIC construction has an impact on the resulting network that needs to be further investigated.

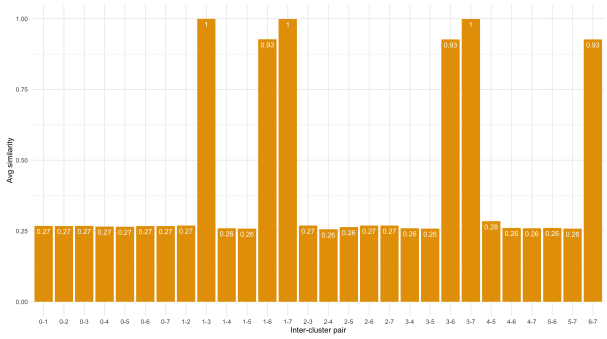
Conclusion

In this paper we presented a novel way to model, visualise and analyse the temporal dynamics of an epidemic outbreak. We applied Transcendental Information Cascades to capture the recurrence and co-occurrence of unique codon identifiers over distinct and temporally ordered nucleotide sequences derived from genetic samples taken from different human subjects. Our case study was focused on the recent outbreak of the novel 2019-nCoV coronavirus. We find clusters and evolution pathways of virus genomes in the constructed Transcendental Information Cascade that are candidates to be investigated further for potential human-to-human transmission paths and genetic evolution of the 2019-nCoV coronavirus.

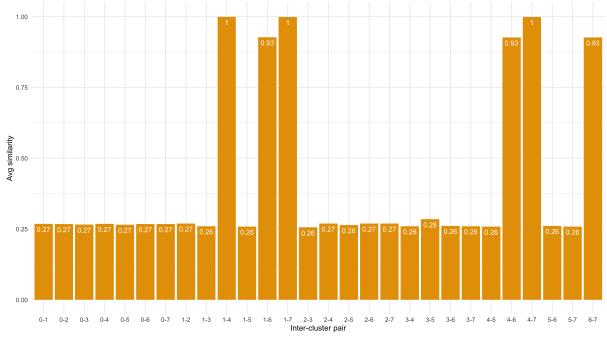
Our study was performed as a snapshot case study on a limited sample of virus data. While this was at the time of this study all data that was available, we will need to re-execute this analysis continuously as more data becomes available to check whether any of our results change. Furthermore, our results indicate that experiments with



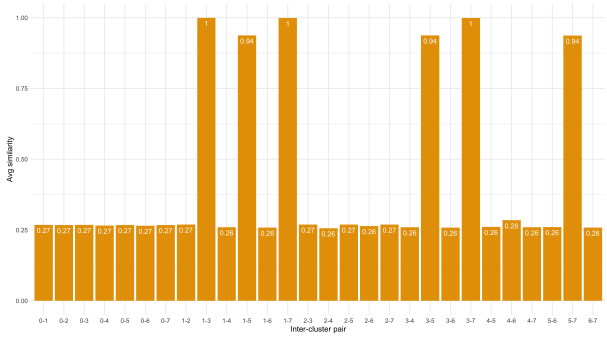
(a)



(b)



(c)



(d)

Figure 5. Overview of inter-cluster similarities for (a) the full TIC network, (b) the +1 reading frame network, (c) the +2 reading frame network, and (d) the +3 reading frame network.

alternative tokenisations are needed, such as weighting the +1, +2 and +3 reading frames differently (or omitting certain frames entirely) depending on their functional role [10]. We also suggest that it will be important to perform a wider variety of analysis of the generated TIC data (e.g. testing of different network clustering methods, application of dynamical systems analyses techniques) to get more profound insights. Our analysis also does not take measurement biases into account that may results from different techniques used by different laboratories for genome extraction and analysis [7].

In summary, the approach presented in this paper is exploratory and hypotheses generating in nature. It does not confirm or reject any of the hypotheses we generated about the potential transmission and evolution pathways nor does it provide causal explanation for the patterns found. However, the purpose of our work is to provide an alternative view to the epidemic dynamics of the 2019-nCoV outbreak (and potential other outbreaks in the future) that is hidden to state-of-the-art methods, and that may trigger geneticists and epidemiologists to look at pathways in epidemic outbreaks they would not normally be aware of.

References

1. H.-J. Bandelt, P. Forster, and A. Röhl. Median-joining networks for inferring intraspecific phylogenies. *Molecular biology and evolution*, 16(1):37–48, 1999.

2. D. Benvenuto, M. Giovannetti, A. Ciccozzi, S. Spoto, S. Angeletti, and M. Ciccozzi. The 2019-new coronavirus epidemic: evidence for virus evolution. *Journal of Medical Virology*, 2020.

3. V. D. Blondel, J.-L. Guillaume, R. Lambiotte, and E. Lefebvre. Fast unfolding of communities in large networks. *Journal of statistical mechanics: theory and experiment*, 2008(10):P10008, 2008.

4. S. Boccaletti, G. Bianconi, R. Criado, C. I. Del Genio, J. Gómez-Gardenes, M. Romance, I. Sendina-Nadal, Z. Wang, and M. Zanin. The structure and dynamics of multilayer networks. *Physics Reports*, 544(1):1–122, 2014.

5. O. Cenciarelli, S. Pietropaoli, A. Malizia, M. Carestia, F. D'Amico, A. Sassolini, D. Di Giovanni, S. Rea, V. Gabbarini, A. Tamburrini, et al. Ebola virus disease 2013-2014 outbreak in west africa: an analysis of the epidemic spread and response. *International journal of microbiology*, 2015, 2015.

6. P. Cliften, P. Sudarsanam, A. Desikan, L. Fulton, B. Fulton, J. Majors, R. Waterston, B. A. Cohen, and M. Johnston. Finding functional features in saccharomyces genomes by phylogenetic footprinting. *science*, 301(5629):71–76, 2003.

7. A. S. Devonshire, A. S. Whale, A. Gutteridge, G. Jones, S. Cowen, C. A. Foy, and J. F. Huggett. Towards standardisation of cell-free dna measurement in plasma: controls for extraction efficiency, fragment size bias and quantification. *Analytical and bioanalytical chemistry*, 406(26):6499–6512, 2014.

8. N. Dong, X. Yang, L. Ye, K. Chen, E. W.-C. Chan, M. Yang, and S. Chen. Genomic and protein structure modelling analysis depicts the origin and infectivity of 2019-ncov, a new coronavirus which caused a pneumonia outbreak in wuhan, china. *bioRxiv*, 2020.

9. A. J. Drummond and A. Rambaut. Beast: Bayesian evolutionary analysis by sampling trees. *BMC evolutionary biology*, 7(1):214, 2007.

10. P. J. Farabaugh and G. R. Björk. How translational accuracy influences reading frame maintenance. *The EMBO journal*, 18(6):1427–1434, 1999.

11. J. Faulkner, M. Schaller, J. H. Park, and L. A. Duncan. Evolved disease-avoidance mechanisms and contemporary xenophobic attitudes. *Group Processes & Intergroup Relations*, 7(4):333–353, 2004.

12. Y. Hu. Efficient, high-quality force-directed graph drawing. *Mathematica Journal*, 10(1):37–71, 2005.

13. M. Kellis, N. Patterson, M. Endrizzi, B. Birren, and E. S. Lander. Sequencing and comparison of yeast species to identify genes and regulatory elements. *Nature*, 423(6937):241, 2003.

14. C. Li, X. Yu, and N. Helal. Similarity analysis of dna sequences based on codon usage. *Chemical physics letters*, 459(1-6):172–174, 2008.

15. T. Liu, J. Hu, M. Kang, L. Lin, H. Zhong, J. Xiao, G. He, T. Song, Q. Huang, Z. Rong, et al. Transmission dynamics of 2019 novel coronavirus (2019-ncov). *bioRxiv*, 2020.

16. M. Luczak-Roesch, K. O'Hara, J. D. Dinneen, and R. Tinati. What an entangled web we weave: An information-centric approach to time-evolving socio-technical systems. *Minds and Machines*, 28(4):709–733, 2018.

17. M. Luczak-Roesch, R. Tinati, M. Van Kleek, and N. Shadbolt. From coincidence to purposeful flow? properties of transcendental information cascades. In *2015 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining (ASONAM)*, pages 633–638. IEEE, 2015.

18. I. Manolopoulou, L. Legarreta, B. C. Emerson, S. Brooks, and S. Tavaré. A bayesian approach to phylogeographic clustering. *Interface focus*, 1(6):909–921, 2011.

19. N. Masuda and P. Holme. Detecting sequences of system states in temporal networks. *Scientific reports*, 9(1):1–11, 2019.

20. G. R. D. S. Pagès H, Aboyoun P. *Biostrings: Efficient manipulation of biological strings*, 2019. R package version 2.54.0.

21. M. A. Porter. Nonlinearity+ networks: A 2020 vision. *arXiv preprint arXiv:1911.03805*, 2019.

22. P. M. Sharp and W.-H. Li. The codon adaptation index-a measure of directional synonymous codon usage bias, and its potential applications. *Nucleic acids research*, 15(3):1281–1295, 1987.

23. R. D. Smith. Responding to global infectious disease outbreaks: lessons from sars on the role of risk perception, communication and management. *Social science & medicine*, 63(12):3113–3123, 2006.

Appendix

The software developed for this particular analysis is part of the open scientific software "R toolchain to construct and analyse Transcendental Information Cascades" that is available via `https://github.com/vuw-c2lab/transcendental-information-cascades/tree/master/input/2020-02-03-2019nCoV`. For reproduction purposes it is necessary to obtain the raw genomic data used in this study from the GISAID EpiFlu Database™.

For further reference we provide the raw results of some of our analysis. We particularly point to the tables that provide references for relationships between nucleotide sequences and the cluster membership of nucleotide sequences.

Table 2. Edge weight between distinct nucleotide sequences in the Transcendental Information Cascade we constructed.

Source sequence	Target sequence	Edge weight
11 - BetaCoV/Wuhan/IPBCAMS-WH-04/2019	12 - BetaCoV/Wuhan/IPBCAMS-WH-03/2019	29885
3 - BetaCoV/Wuhan/IV DC-HB-01/2019	4 - BetaCoV/Wuhan/IV DC-HB-05/2019	29883
4 - BetaCoV/Wuhan/IV DC-HB-05/2019	5 - BetaCoV/Wuhan/WIV04/2019	29883
66 - BetaCoV/USA/WA1-A12/2020	67 - BetaCoV/USA/W A 1-F6/2020	29880
74 - BetaCoV/USA/CA3/2020	75 - BetaCoV/USA/CA4/2020	29880
17 - BetaCoV/China/WHU01/2020	18 - BetaCoV/China/WHU02/2020	29879
14 - BetaCoV/Wuhan/IV DC-HB-04/2020	15 - BetaCoV/Wuhan/IPBCAMS-WH-05/2020	29872
12 - BetaCoV/Wuhan/IPBCAMS-WH-03/2019	13 - BetaCoV/Wuhan/IPBCAMS-WH-02/2019	29870
13 - BetaCoV/Wuhan/IPBCAMS-WH-02/2019	14 - BetaCoV/Wuhan/IV DC-HB-04/2020	29867
75 - BetaCoV/USA/CA4/2020	76 - BetaCoV/USA/CA5/2020	29865
48 - BetaCoV/USA/CA2/2020	49 - BetaCoV/USA/AZ1/2020	29862
22 - BetaCoV/Shenzhen/HKU-SZ-005/2020	23 - BetaCoV/Jiangxi/IV DC-JX-002/2020	29856
27 - BetaCoV/Guangdong/20SFO0 12/2020	28 - BetaCoV/Guangdong/20SFO0 13/2020	29843
28 - BetaCoV/Guangdong/20SFO0 13/2020	29 - BetaCoV/Guangdong/20SFO0 14/2020	29831
29 - BetaCoV/Guangdong/20SFO0 14/2020	30 - BetaCoV/Guangdong/20SF025/2020	29831
71 - BetaCoV/England/01/2020	72 - BetaCoV/England/02/2020	29830
52 - BetaCo V/Foshan/20SF207/2020	53 - BetaCo V/Foshan/20SF2 10/2020	29828
51 - BetaCoV/Guangzhou/20SF206/2020	52 - BetaCo V/Foshan/20SF207/2020	29825
25 - BetaCoV/Shenzhen/SZTH-00 1/2020	26 - BetaCoV/Shenzhen/SZTH-002/2020	29813
53 - BetaCo V/Foshan/20SF2 10/2020	54 - BetaCoV/Foshan/20SF21 1/2020	29801
50 - BetaCoV/Guangdong/20SF174/2020	51 - BetaCoV/Guangzhou/20SF206/2020	29797
73 - BetaCoV/Finland/1/2020	74 - BetaCoV/USA/CA3/2020	29665
72 - BetaCoV/England/02/2020	73 - BetaCoV/Finland/1/2020	29643
1 - BetaCoV/Wuhan/IPBCAMS-WH-01/2019	3 - BetaCoV/Wuhan/IV DC-HB-01/2019	29346
37 - BetaCoV/Yunnan/IVDC- Y N-003/2020	39 - BetaCoV/Chongqing/IVDC-CQ-00 1/2020	29332
26 - BetaCoV/Shenzhen/SZTH-002/2020	31 - BetaCoV/Sichuan/ITVDC-SC-00 1/2020	29315
24 - BetaCoV/Nonthaburi/74/2020	27 - BetaCoV/Guangdong/20SFO0 12/2020	29290
39 - BetaCoV/Chongqing/IVDC-CQ-00 1/2020	41 - BetaCoV/USA/WA 1/2020	29274
23 - BetaCoV/Jiangxi/IV DC-JX-002/2020	25 - BetaCoV/Shenzhen/SZTH-00 1/2020	29248
41 - BetaCoV/USA/WA 1/2020	43 - BetaCoV/Shandong/IVDC-SD-00 1/2020	29142
54 - BetaCoV/Foshan/20SF21 1/2020	57 - BetaCoV/Guangdong/20SF201/2020	28741
49 - BetaCoV/USA/AZ1/2020	56 - BetaCoV/USA/CA1/2020	28651
40 - BetaCoV/Beijing/IV DC-BJ-005/2020	44 - BetaCoV/Jiangsu/IVDC-JS-00 1/2020	28650
20 - BetaCoV/Nonthaburi/6 1/2020	24 - BetaCoV/Nonthaburi/74/2020	28586
63 - BetaCoV/Australia/VICO1/2020	66 - BetaCoV/USA/WA1-A12/2020	28557
35 - BetaCoV/Guangdong/20SF028/2020	38 - BetaCoV/Guangdong/20SF040/2020	28532
43 - BetaCoV/Shandong/IVDC-SD-00 1/2020	46 - BetaCoV/USA/IL 1/2020	28469
56 - BetaCoV/USA/CA1/2020	60 - BetaCoV/Singapore/ 1/2020	28287
65 - BetaCoV/Korea/KCDC03/2020	70 - BetaCoV/Australia/QLD0O1/2020	28136
68 - BetaCoV/Singapore/2/2020	77 - BetaCo V/France/IDF05 15/2020	28051
30 - BetaCoV/Guangdong/20SF025/2020	35 - BetaCoV/Guangdong/20SF028/2020	27962
67 - BetaCoV/USA/W A 1-F6/2020	71 - BetaCoV/England/01/2020	27952
31 - BetaCoV/Sichuan/ITVDC-SC-00 1/2020	37 - BetaCoV/Yunnan/IVDC- Y N-003/2020	27711
10 - BetaCoV/Wuhan/HBCDC-HB-01/2019	20 - BetaCoV/Nonthaburi/6 1/2020	27513
62 - BetaCoV/Australia/NS WO 1/2020	69 - BetaCoV/Germany/BavPat 1/2020	27286
76 - BetaCoV/USA/CA5/2020	82 - BetaCoV/Belgium/GHB-0302 1/2020	27215
15 - BetaCoV/Wuhan/IPBCAMS-WH-05/2020	22 - BetaCoV/Shenzhen/HKU-SZ-005/2020	27049
5 - BetaCoV/Wuhan/WIV04/2019	11 - BetaCoV/Wuhan/IPBCAMS-WH-04/2019	26905
38 - BetaCoV/Guangdong/20SF040/2020	58 - BetaCo V/France/IDF0372/2020	26795
58 - BetaCo V/France/IDF0372/2020	78 - BetaCov/France/IDF0626/2020	26624
18 - BetaCoV/China/WHU02/2020	40 - BetaCoV/Beijing/IV DC-BJ-005/2020	25949
32 - BetaCoV/Zhejiang/WZ-0 1/2020	59 - BetaCoV/France/IDF0373/2020	25427
44 - BetaCoV/Jiangsu/IVDC-JS-00 1/2020	68 - BetaCoV/Singapore/2/2020	22332
60 - BetaCoV/Singapore/ 1/2020	61 - BetaCoV/Chonggqing/ZX0 1/2020	21150
47 - BetaCoV/Chonggqing/Y C0 1/2020	48 - BetaCoV/USA/CA2/2020	21147
46 - BetaCoV/USA/IL 1/2020	47 - BetaCoV/Chonggqing/Y C0 1/2020	21143
61 - BetaCoV/Chonggqing/ZX0 1/2020	63 - BetaCoV/Australia/VICO1/2020	20532
45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	55 - BetaCoV/Taiwan/2/2020	20288
33 - BetaCoV/Shenzhen/SZTH-003/2020	34 - BetaCoV/Shenzhen/SZTH-004/2020	20102
46 - BetaCoV/USA/IL 1/2020	48 - BetaCoV/USA/CA2/2020	8710
60 - BetaCoV/Singapore/ 1/2020	63 - BetaCoV/Australia/VICO1/2020	8389
47 - BetaCoV/Chonggqing/Y C0 1/2020	61 - BetaCoV/Chonggqing/ZX0 1/2020	7936
55 - BetaCoV/Taiwan/2/2020	81 - BetaCoV/Singapore/3/2020	4399
55 - BetaCoV/Taiwan/2/2020	68 - BetaCoV/Singapore/2/2020	3424
44 - BetaCoV/Jiangsu/IVDC-JS-00 1/2020	55 - BetaCoV/Taiwan/2/2020	3393
55 - BetaCoV/Taiwan/2/2020	64 - BetaCoV/Japan/AI/I-004/2020	904
5 - BetaCoV/Wuhan/WIV04/2019	6 - BetaCoV/Wuhan/WIV02/2019	848
62 - BetaCoV/Australia/NS WO 1/2020	63 - BetaCoV/Australia/VICO1/2020	838
69 - BetaCoV/Germany/BavPat 1/2020	71 - BetaCoV/England/01/2020	826
67 - BetaCoV/USA/W A 1-F6/2020	69 - BetaCoV/Germany/BavPat 1/2020	815
10 - BetaCoV/Wuhan/HBCDC-HB-01/2019	16 - BetaCov/Wuhan/WH03/2020	812
16 - BetaCov/Wuhan/WH03/2020	20 - BetaCoV/Nonthaburi/6 1/2020	806
78 - BetaCov/France/IDF0626/2020	81 - BetaCoV/Singapore/3/2020	779
61 - BetaCoV/Chonggqing/ZX0 1/2020	62 - BetaCoV/Australia/NS WO 1/2020	773
59 - BetaCoV/France/IDF0373/2020	65 - BetaCoV/Korea/KCDC03/2020	773
6 - BetaCoV/Wuhan/WIV02/2019	11 - BetaCoV/Wuhan/IPBCAMS-WH-04/2019	771
35 - BetaCoV/Guangdong/20SF028/2020	36 - BetaCoV/Zhejiang/WZ-02/2020	771
36 - BetaCoV/Zhejiang/WZ-02/2020	38 - BetaCoV/Guangdong/20SF040/2020	767
45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	46 - BetaCoV/USA/IL 1/2020	762
78 - BetaCov/France/IDF0626/2020	80 - BetaCoV/Taiwan/NTU01/2020	758
8 - BetaCoV/Wuhan/WIV06/2019	10 - BetaCoV/Wuhan/HBCDC-HB-01/2019	755

Table 3. Edge weight between distinct nucleotide sequences in the Transcendental Information Cascade we constructed (contd.).

Source sequence	Target sequence	Edge weight
43 - BetaCoV/Shandong/IVDC-SD-00 1/2020	45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	754
19 - BetaCov/Wuhan/WH04/2020	22 - BetaCoV/Shenzhen/HKU-SZ-005/2020	748
34 - BetaCoV/Shenzhen/SZTH-004/2020	36 - BetaCoV/Zhejiang/WZ-02/2020	747
57 - BetaCoV/Guangdong/20SF201/2020	58 - BetaCo V/France/IDF0372/2020	742
69 - BetaCoV/Germany/BavPat 1/2020	79 - BetaCoV/Australia/QLD02/2020	740
15 - BetaCoV/Wuhan/IPBCAMS-WH-05/2020	19 - BetaCov/Wuhan/WH04/2020	731
20 - BetaCoV/Nonthaburi/6 1/2020	21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	727
6 - BetaCoV/Wuhan/WIV02/2019	7 - BetaCoV/Wuhan/WIV05/2019	725
21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	24 - BetaCoV/Nonthaburi/74/2020	715
80 - BetaCoV/Taiwan/NTU01/2020	81 - BetaCoV/Singapore/3/2020	714
9 - BetaCoV/Wuhan/WIV07/2019	17 - BetaCoV/China/WHU01/2020	713
5 - BetaCoV/Wuhan/WIV04/2019	7 - BetaCoV/Wuhan/WIV05/2019	711
7 - BetaCoV/Wuhan/WIV05/2019	19 - BetaCov/Wuhan/WH04/2020	703
76 - BetaCoV/USA/CA5/2020	79 - BetaCoV/Australia/QLD02/2020	700
79 - BetaCoV/Australia/QLD02/2020	82 - BetaCoV/Belgium/GHB-0302 1/2020	700
7 - BetaCoV/Wuhan/WIV05/2019	11 - BetaCoV/Wuhan/IPBCAMS-WH-04/2019	698
41 - BetaCoV/USA/WA 1/2020	42 - BetaCoV/Hangzhou/HZCDC000 1/2020	698
42 - BetaCoV/Hangzhou/HZCDC000 1/2020	43 - BetaCoV/Shandong/IVDC-SD-00 1/2020	698
63 - BetaCoV/Australia/VICO1/2020	64 - BetaCoV/Japan/AI/I-004/2020	694
38 - BetaCoV/Guangdong/20SF040/2020	50 - BetaCoV/Guangdong/20SF174/2020	693
68 - BetaCoV/Singapore/2/2020	70 - BetaCoV/Australia/QLD0O1/2020	687
2 - BetaCov/Wuhan/WHO01/2019	9 - BetaCoV/Wuhan/WIV07/2019	686
21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	33 - BetaCoV/Shenzhen/SZTH-003/2020	685
21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	50 - BetaCoV/Guangdong/20SF174/2020	685
55 - BetaCoV/Taiwan/2/2020	56 - BetaCoV/USA/CA1/2020	685
36 - BetaCoV/Zhejiang/WZ-02/2020	50 - BetaCoV/Guangdong/20SF174/2020	678
55 - BetaCoV/Taiwan/2/2020	62 - BetaCoV/Australia/NS WO 1/2020	677
49 - BetaCoV/USA/AZ1/2020	55 - BetaCoV/Taiwan/2/2020	676
65 - BetaCoV/Korea/KCDC03/2020	68 - BetaCoV/Singapore/2/2020	675
70 - BetaCoV/Australia/QLD0O1/2020	77 - BetaCo V/France/IDF05 15/2020	675
16 - BetaCov/Wuhan/WH03/2020	21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	674
64 - BetaCoV/Japan/AI/I-004/2020	66 - BetaCoV/USA/WA1-A12/2020	674
62 - BetaCoV/Australia/NS WO 1/2020	64 - BetaCoV/Japan/AI/I-004/2020	671
19 - BetaCov/Wuhan/WH04/2020	42 - BetaCoV/Hangzhou/HZCDC000 1/2020	666
42 - BetaCoV/Hangzhou/HZCDC000 1/2020	45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	665
8 - BetaCoV/Wuhan/WIV06/2019	16 - BetaCov/Wuhan/WH03/2020	664
21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	36 - BetaCoV/Zhejiang/WZ-02/2020	654
42 - BetaCoV/Hangzhou/HZCDC000 1/2020	64 - BetaCoV/Japan/AI/I-004/2020	654
9 - BetaCoV/Wuhan/WIV07/2019	32 - BetaCoV/Zhejiang/WZ-0 1/2020	651
30 - BetaCoV/Guangdong/20SF025/2020	33 - BetaCoV/Shenzhen/SZTH-003/2020	646
18 - BetaCoV/China/WHU02/2020	32 - BetaCoV/Zhejiang/WZ-0 1/2020	641
64 - BetaCoV/Japan/AI/I-004/2020	69 - BetaCoV/Germany/BavPat 1/2020	637
42 - BetaCoV/Hangzhou/HZCDC000 1/2020	62 - BetaCoV/Australia/NS WO 1/2020	630
32 - BetaCoV/Zhejiang/WZ-0 1/2020	40 - BetaCoV/Beijing/IV DC-BJ-005/2020	629
34 - BetaCoV/Shenzhen/SZTH-004/2020	35 - BetaCoV/Guangdong/20SF028/2020	628
7 - BetaCoV/Wuhan/WIV05/2019	45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	625
64 - BetaCoV/Japan/AI/I-004/2020	79 - BetaCoV/Australia/QLD02/2020	619
19 - BetaCov/Wuhan/WH04/2020	45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	618
8 - BetaCoV/Wuhan/WIV06/2019	50 - BetaCoV/Guangdong/20SF174/2020	616
2 - BetaCov/Wuhan/WHO01/2019	17 - BetaCoV/China/WHU01/2020	613
43 - BetaCoV/Shandong/IVDC-SD-00 1/2020	44 - BetaCoV/Jiangsu/IVDC-JS-00 1/2020	608
57 - BetaCoV/Guangdong/20SF201/2020	80 - BetaCoV/Taiwan/NTU01/2020	607
16 - BetaCov/Wuhan/WH03/2020	36 - BetaCoV/Zhejiang/WZ-02/2020	603
59 - BetaCoV/France/IDF0373/2020	68 - BetaCoV/Singapore/2/2020	602
34 - BetaCoV/Shenzhen/SZTH-004/2020	40 - BetaCoV/Beijing/IV DC-BJ-005/2020	598
36 - BetaCoV/Zhejiang/WZ-02/2020	80 - BetaCoV/Taiwan/NTU01/2020	597
16 - BetaCov/Wuhan/WH03/2020	33 - BetaCoV/Shenzhen/SZTH-003/2020	596
39 - BetaCoV/Chongqing/IVDC-CQ-00 1/2020	40 - BetaCoV/Beijing/IV DC-BJ-005/2020	595
16 - BetaCov/Wuhan/WH03/2020	50 - BetaCoV/Guangdong/20SF174/2020	595
8 - BetaCoV/Wuhan/WIV06/2019	21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	594
44 - BetaCoV/Jiangsu/IVDC-JS-00 1/2020	46 - BetaCoV/USA/IL 1/2020	592
40 - BetaCoV/Beijing/IV DC-BJ-005/2020	41 - BetaCoV/USA/WA 1/2020	591
79 - BetaCoV/Australia/QLD02/2020	80 - BetaCoV/Taiwan/NTU01/2020	590
64 - BetaCoV/Japan/AI/I-004/2020	65 - BetaCoV/Korea/KCDC03/2020	588
6 - BetaCoV/Wuhan/WIV02/2019	19 - BetaCov/Wuhan/WH04/2020	587
8 - BetaCoV/Wuhan/WIV06/2019	36 - BetaCoV/Zhejiang/WZ-02/2020	587
9 - BetaCoV/Wuhan/WIV07/2019	65 - BetaCoV/Korea/KCDC03/2020	587
42 - BetaCoV/Hangzhou/HZCDC000 1/2020	79 - BetaCoV/Australia/QLD02/2020	587
6 - BetaCoV/Wuhan/WIV02/2019	42 - BetaCoV/Hangzhou/HZCDC000 1/2020	586
2 - BetaCov/Wuhan/WHO01/2019	32 - BetaCoV/Zhejiang/WZ-0 1/2020	585
19 - BetaCov/Wuhan/WH04/2020	79 - BetaCoV/Australia/QLD02/2020	585
8 - BetaCoV/Wuhan/WIV06/2019	33 - BetaCoV/Shenzhen/SZTH-003/2020	584
55 - BetaCoV/Taiwan/2/2020	58 - BetaCo V/France/IDF0372/2020	584
7 - BetaCoV/Wuhan/WIV05/2019	62 - BetaCoV/Australia/NS WO 1/2020	584
34 - BetaCoV/Shenzhen/SZTH-004/2020	50 - BetaCoV/Guangdong/20SF174/2020	583
44 - BetaCoV/Jiangsu/IVDC-JS-00 1/2020	59 - BetaCoV/France/IDF0373/2020	581
76 - BetaCoV/USA/CA5/2020	77 - BetaCo V/France/IDF05 15/2020	580
8 - BetaCoV/Wuhan/WIV06/2019	9 - BetaCoV/Wuhan/WIV07/2019	579
67 - BetaCoV/USA/W A 1-F6/2020	68 - BetaCoV/Singapore/2/2020	579
19 - BetaCov/Wuhan/WH04/2020	62 - BetaCoV/Australia/NS WO 1/2020	574
15 - BetaCoV/Wuhan/IPBCAMS-WH-05/2020	17 - BetaCoV/China/WHU01/2020	571
57 - BetaCoV/Guangdong/20SF201/2020	81 - BetaCoV/Singapore/3/2020	570
19 - BetaCov/Wuhan/WH04/2020	64 - BetaCoV/Japan/AI/I-004/2020	557
68 - BetaCoV/Singapore/2/2020	69 - BetaCoV/Germany/BavPat 1/2020	557
70 - BetaCoV/Australia/QLD0O1/2020	79 - BetaCoV/Australia/QLD02/2020	556
44 - BetaCoV/Jiangsu/IVDC-JS-00 1/2020	50 - BetaCoV/Guangdong/20SF174/2020	551
19 - BetaCov/Wuhan/WH04/2020	33 - BetaCoV/Shenzhen/SZTH-003/2020	550

Table 4. Edge weight between distinct nucleotide sequences in the Transcendental Information Cascade we constructed (contd.).

Source sequence	Target sequence	Edge weight
23 - BetaCoV/Jiangxi/IV DC-JX-002/2020	24 - BetaCoV/Nonthaburi/74/2020	546
58 - BetaCo V/France/IDF0372/2020	59 - BetaCoV/France/IDF0373/2020	546
77 - BetaCo V/France/IDF05 15/2020	78 - BetaCov/France/IDF0626/2020	545
10 - BetaCoV/Wuhan/HBCDC-HB-01/2019	11 - BetaCoV/Wuhan/IPBCAMS-WH-04/2019	544
24 - BetaCoV/Nonthaburi/74/2020	25 - BetaCoV/Shenzhen/SZTH-00 1/2020	544
26 - BetaCoV/Shenzhen/SZTH-002/2020	27 - BetaCoV/Guangdong/20SFO0 12/2020	544
30 - BetaCoV/Guangdong/20SF025/2020	31 - BetaCoV/Sichuan/ITVDC-SC-00 1/2020	544
37 - BetaCoV/Yunnan/IVDC- Y N-003/2020	38 - BetaCoV/Guangdong/20SF040/2020	544
38 - BetaCoV/Guangdong/20SF040/2020	39 - BetaCoV/Chongqing/IVDC-CQ-00 1/2020	544
59 - BetaCoV/France/IDF0373/2020	62 - BetaCoV/Australia/NS WO 1/2020	544
35 - BetaCoV/Guangdong/20SF028/2020	37 - BetaCoV/Yunnan/IVDC- Y N-003/2020	540
19 - BetaCov/Wuhan/WH04/2020	21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	539
77 - BetaCo V/France/IDF05 15/2020	81 - BetaCoV/Singapore/3/2020	539
6 - BetaCoV/Wuhan/WIV02/2019	10 - BetaCoV/Wuhan/HBCDC-HB-01/2019	538
7 - BetaCoV/Wuhan/WIV05/2019	64 - BetaCoV/Japan/AI/I-004/2020	536
2 - BetaCov/Wuhan/WHO01/2019	65 - BetaCoV/Korea/KCDC03/2020	536
2 - BetaCov/Wuhan/WHO01/2019	3 - BetaCoV/Wuhan/IV DC-HB-01/2019	535
54 - BetaCoV/Foshan/20SF21 1/2020	55 - BetaCoV/Taiwan/2/2020	535
1 - BetaCoV/Wuhan/IPBCAMS-WH-01/2019	2 - BetaCov/Wuhan/WHO01/2019	534
18 - BetaCoV/China/WHU02/2020	20 - BetaCoV/Nonthaburi/6 1/2020	534
68 - BetaCoV/Singapore/2/2020	71 - BetaCoV/England/01/2020	534
7 - BetaCoV/Wuhan/WIV05/2019	42 - BetaCoV/Hangzhou/HZCDC000 1/2020	533
49 - BetaCoV/USA/AZ1/2020	50 - BetaCoV/Guangdong/20SF174/2020	533
15 - BetaCoV/Wuhan/IPBCAMS-WH-05/2020	16 - BetaCov/Wuhan/WH03/2020	532
20 - BetaCoV/Nonthaburi/6 1/2020	22 - BetaCoV/Shenzhen/HKU-SZ-005/2020	532
21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	22 - BetaCoV/Shenzhen/HKU-SZ-005/2020	532
56 - BetaCoV/USA/CA1/2020	57 - BetaCoV/Guangdong/20SF201/2020	532
30 - BetaCoV/Guangdong/20SF025/2020	32 - BetaCoV/Zhejiang/WZ-0 1/2020	531
2 - BetaCov/Wuhan/WHO01/2019	6 - BetaCoV/Wuhan/WIV02/2019	530
56 - BetaCoV/USA/CA1/2020	58 - BetaCo V/France/IDF0372/2020	530
58 - BetaCo V/France/IDF0372/2020	60 - BetaCoV/Singapore/ 1/2020	529
69 - BetaCoV/Germany/BavPat 1/2020	77 - BetaCo V/France/IDF05 15/2020	528
55 - BetaCoV/Taiwan/2/2020	57 - BetaCoV/Guangdong/20SF201/2020	526
57 - BetaCoV/Guangdong/20SF201/2020	68 - BetaCoV/Singapore/2/2020	526
80 - BetaCoV/Taiwan/NTU01/2020	82 - BetaCoV/Belgium/GHB-0302 1/2020	526
18 - BetaCoV/China/WHU02/2020	22 - BetaCoV/Shenzhen/HKU-SZ-005/2020	525
70 - BetaCoV/Australia/QLD0O1/2020	78 - BetaCov/France/IDF0626/2020	525
76 - BetaCoV/USA/CA5/2020	78 - BetaCov/France/IDF0626/2020	525
18 - BetaCoV/China/WHU02/2020	19 - BetaCov/Wuhan/WH04/2020	524
70 - BetaCoV/Australia/QLD0O1/2020	80 - BetaCoV/Taiwan/NTU01/2020	524
38 - BetaCoV/Guangdong/20SF040/2020	40 - BetaCoV/Beijing/IV DC-BJ-005/2020	523
45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	50 - BetaCoV/Guangdong/20SF174/2020	522
54 - BetaCoV/Foshan/20SF21 1/2020	56 - BetaCoV/USA/CA1/2020	522
44 - BetaCoV/Jiangsu/IVDC-JS-00 1/2020	65 - BetaCoV/Korea/KCDC03/2020	521
34 - BetaCoV/Shenzhen/SZTH-004/2020	80 - BetaCoV/Taiwan/NTU01/2020	519
32 - BetaCoV/Zhejiang/WZ-0 1/2020	35 - BetaCoV/Guangdong/20SF028/2020	518
62 - BetaCoV/Australia/NS WO 1/2020	68 - BetaCoV/Singapore/2/2020	517
2 - BetaCov/Wuhan/WHO01/2019	8 - BetaCoV/Wuhan/WIV06/2019	516
31 - BetaCoV/Sichuan/ITVDC-SC-00 1/2020	35 - BetaCoV/Guangdong/20SF028/2020	516
6 - BetaCoV/Wuhan/WIV02/2019	45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	516
38 - BetaCoV/Guangdong/20SF040/2020	45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	516
58 - BetaCo V/France/IDF0372/2020	62 - BetaCoV/Australia/NS WO 1/2020	515
69 - BetaCoV/Germany/BavPat 1/2020	78 - BetaCov/France/IDF0626/2020	514
59 - BetaCoV/France/IDF0373/2020	64 - BetaCoV/Japan/AI/I-004/2020	512
70 - BetaCoV/Australia/QLD0O1/2020	71 - BetaCoV/England/01/2020	512
10 - BetaCoV/Wuhan/HBCDC-HB-01/2019	17 - BetaCoV/China/WHU01/2020	511
65 - BetaCoV/Korea/KCDC03/2020	66 - BetaCoV/USA/WA1-A12/2020	511
57 - BetaCoV/Guangdong/20SF201/2020	60 - BetaCoV/Singapore/ 1/2020	510
42 - BetaCoV/Hangzhou/HZCDC000 1/2020	44 - BetaCoV/Jiangsu/IVDC-JS-00 1/2020	509
21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	80 - BetaCoV/Taiwan/NTU01/2020	509
40 - BetaCoV/Beijing/IV DC-BJ-005/2020	42 - BetaCoV/Hangzhou/HZCDC000 1/2020	508
55 - BetaCoV/Taiwan/2/2020	79 - BetaCoV/Australia/QLD02/2020	507
31 - BetaCoV/Sichuan/ITVDC-SC-00 1/2020	33 - BetaCoV/Shenzhen/SZTH-003/2020	505
16 - BetaCov/Wuhan/WH03/2020	80 - BetaCoV/Taiwan/NTU01/2020	505
78 - BetaCov/France/IDF0626/2020	82 - BetaCoV/Belgium/GHB-0302 1/2020	505
34 - BetaCoV/Shenzhen/SZTH-004/2020	37 - BetaCoV/Yunnan/IVDC- Y N-003/2020	504
18 - BetaCoV/China/WHU02/2020	21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	503
7 - BetaCoV/Wuhan/WIV05/2019	79 - BetaCoV/Australia/QLD02/2020	502
16 - BetaCov/Wuhan/WH03/2020	32 - BetaCoV/Zhejiang/WZ-0 1/2020	501
5 - BetaCoV/Wuhan/WIV04/2019	8 - BetaCoV/Wuhan/WIV06/2019	497
16 - BetaCov/Wuhan/WH03/2020	17 - BetaCoV/China/WHU01/2020	497
15 - BetaCoV/Wuhan/IPBCAMS-WH-05/2020	20 - BetaCoV/Nonthaburi/6 1/2020	497
31 - BetaCoV/Sichuan/ITVDC-SC-00 1/2020	32 - BetaCoV/Zhejiang/WZ-0 1/2020	497
59 - BetaCoV/France/IDF0373/2020	60 - BetaCoV/Singapore/ 1/2020	496
76 - BetaCoV/USA/CA5/2020	80 - BetaCoV/Taiwan/NTU01/2020	494
19 - BetaCov/Wuhan/WH04/2020	20 - BetaCoV/Nonthaburi/6 1/2020	493
32 - BetaCoV/Zhejiang/WZ-0 1/2020	42 - BetaCoV/Hangzhou/HZCDC000 1/2020	493
58 - BetaCo V/France/IDF0372/2020	65 - BetaCoV/Korea/KCDC03/2020	493
63 - BetaCoV/Australia/VICO1/2020	65 - BetaCoV/Korea/KCDC03/2020	492
6 - BetaCoV/Wuhan/WIV02/2019	9 - BetaCoV/Wuhan/WIV07/2019	491
34 - BetaCoV/Shenzhen/SZTH-004/2020	42 - BetaCoV/Hangzhou/HZCDC000 1/2020	489
8 - BetaCoV/Wuhan/WIV06/2019	11 - BetaCoV/Wuhan/IPBCAMS-WH-04/2019	488
32 - BetaCoV/Zhejiang/WZ-0 1/2020	33 - BetaCoV/Shenzhen/SZTH-003/2020	488
36 - BetaCoV/Zhejiang/WZ-02/2020	37 - BetaCoV/Yunnan/IVDC- Y N-003/2020	488
36 - BetaCoV/Zhejiang/WZ-02/2020	40 - BetaCoV/Beijing/IV DC-BJ-005/2020	488
69 - BetaCoV/Germany/BavPat 1/2020	70 - BetaCoV/Australia/QLD0O1/2020	487
15 - BetaCoV/Wuhan/IPBCAMS-WH-05/2020	21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	485
42 - BetaCoV/Hangzhou/HZCDC000 1/2020	59 - BetaCoV/France/IDF0373/2020	485
2 - BetaCov/Wuhan/WHO01/2019	10 - BetaCoV/Wuhan/HBCDC-HB-01/2019	484
7 - BetaCoV/Wuhan/WIV05/2019	16 - BetaCov/Wuhan/WH03/2020	483
34 - BetaCoV/Shenzhen/SZTH-004/2020	81 - BetaCoV/Singapore/3/2020	483
5 - BetaCoV/Wuhan/WIV04/2019	10 - BetaCoV/Wuhan/HBCDC-HB-01/2019	482
9 - BetaCoV/Wuhan/WIV07/2019	11 - BetaCoV/Wuhan/IPBCAMS-WH-04/2019	482
7 - BetaCoV/Wuhan/WIV05/2019	17 - BetaCoV/China/WHU01/2020	482
59 - BetaCoV/France/IDF0373/2020	78 - BetaCov/France/IDF0626/2020	482
16 - BetaCov/Wuhan/WH03/2020	19 - BetaCov/Wuhan/WH04/2020	481
18 - BetaCoV/China/WHU02/2020	33 - BetaCoV/Shenzhen/SZTH-003/2020	481
19 - BetaCov/Wuhan/WH04/2020	36 - BetaCoV/Zhejiang/WZ-02/2020	481
67 - BetaCoV/USA/W A 1-F6/2020	70 - BetaCoV/Australia/QLD0O1/2020	481
6 - BetaCoV/Wuhan/WIV02/2019	8 - BetaCoV/Wuhan/WIV06/2019	480

Table 5. Edge weight between distinct nucleotide sequences in the Transcendental Information Cascade we constructed (contd.).

Source sequence	Target sequence	Edge weight
57 - BetaCoV/Guangdong/20SF201/2020	59 - BetaCoV/France/IDF0373/2020	479
77 - BetaCo V/France/IDF05 15/2020	80 - BetaCoV/Taiwan/NTU01/2020	479
16 - BetaCov/Wuhan/WH03/2020	22 - BetaCoV/Shenzhen/HKU-SZ-005/2020	478
6 - BetaCoV/Wuhan/WIV02/2019	64 - BetaCoV/Japan/AI/I-004/2020	478
58 - BetaCo V/France/IDF0372/2020	68 - BetaCoV/Singapore/2/2020	478
57 - BetaCoV/Guangdong/20SF201/2020	79 - BetaCoV/Australia/QLD02/2020	478
21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	32 - BetaCoV/Zhejiang/WZ-0 1/2020	477
34 - BetaCoV/Shenzhen/SZTH-004/2020	45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	477
36 - BetaCoV/Zhejiang/WZ-02/2020	45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	477
57 - BetaCoV/Guangdong/20SF201/2020	62 - BetaCoV/Australia/NS WO 1/2020	477
79 - BetaCoV/Australia/QLD02/2020	81 - BetaCoV/Singapore/3/2020	477
34 - BetaCoV/Shenzhen/SZTH-004/2020	65 - BetaCoV/Korea/KCDC03/2020	476
81 - BetaCoV/Singapore/3/2020	82 - BetaCoV/Belgium/GHB-0302 1/2020	474
7 - BetaCoV/Wuhan/WIV05/2019	8 - BetaCoV/Wuhan/WIV06/2019	472
9 - BetaCoV/Wuhan/WIV07/2019	10 - BetaCoV/Wuhan/HBCDC-HB-01/2019	472
6 - BetaCoV/Wuhan/WIV02/2019	17 - BetaCoV/China/WHU01/2020	472
56 - BetaCoV/USA/CA1/2020	59 - BetaCoV/France/IDF0373/2020	472
78 - BetaCov/France/IDF0626/2020	79 - BetaCoV/Australia/QLD02/2020	472
44 - BetaCoV/Jiangsu/IVDC-JS-00 1/2020	45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	471
36 - BetaCoV/Zhejiang/WZ-02/2020	42 - BetaCoV/Hangzhou/HZCDC000 1/2020	470
2 - BetaCov/Wuhan/WHO01/2019	7 - BetaCoV/Wuhan/WIV05/2019	469
42 - BetaCoV/Hangzhou/HZCDC000 1/2020	50 - BetaCoV/Guangdong/20SF174/2020	469
6 - BetaCoV/Wuhan/WIV02/2019	62 - BetaCoV/Australia/NS WO 1/2020	469
65 - BetaCoV/Korea/KCDC03/2020	69 - BetaCoV/Germany/BavPat 1/2020	469
9 - BetaCoV/Wuhan/WIV07/2019	16 - BetaCov/Wuhan/WH03/2020	468
77 - BetaCo V/France/IDF05 15/2020	79 - BetaCoV/Australia/QLD02/2020	468
64 - BetaCoV/Japan/AI/I-004/2020	80 - BetaCoV/Taiwan/NTU01/2020	468
19 - BetaCov/Wuhan/WH04/2020	32 - BetaCoV/Zhejiang/WZ-0 1/2020	467
38 - BetaCoV/Guangdong/20SF040/2020	42 - BetaCoV/Hangzhou/HZCDC000 1/2020	467
6 - BetaCoV/Wuhan/WIV02/2019	21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	466
32 - BetaCoV/Zhejiang/WZ-0 1/2020	37 - BetaCoV/Yunnan/IVDC- Y N-003/2020	466
31 - BetaCoV/Sichuan/ITVDC-SC-00 1/2020	36 - BetaCoV/Zhejiang/WZ-02/2020	465
55 - BetaCoV/Taiwan/2/2020	65 - BetaCoV/Korea/KCDC03/2020	464
10 - BetaCoV/Wuhan/HBCDC-HB-01/2019	19 - BetaCov/Wuhan/WH04/2020	463
2 - BetaCov/Wuhan/WHO01/2019	19 - BetaCov/Wuhan/WH04/2020	462
69 - BetaCoV/Germany/BavPat 1/2020	81 - BetaCoV/Singapore/3/2020	462
55 - BetaCoV/Taiwan/2/2020	59 - BetaCoV/France/IDF0373/2020	461
7 - BetaCoV/Wuhan/WIV05/2019	9 - BetaCoV/Wuhan/WIV07/2019	460
32 - BetaCoV/Zhejiang/WZ-0 1/2020	36 - BetaCoV/Zhejiang/WZ-02/2020	460
59 - BetaCoV/France/IDF0373/2020	81 - BetaCoV/Singapore/3/2020	460
7 - BetaCoV/Wuhan/WIV05/2019	10 - BetaCoV/Wuhan/HBCDC-HB-01/2019	458
9 - BetaCoV/Wuhan/WIV07/2019	42 - BetaCoV/Hangzhou/HZCDC000 1/2020	458
36 - BetaCoV/Zhejiang/WZ-02/2020	64 - BetaCoV/Japan/AI/I-004/2020	456
58 - BetaCo V/France/IDF0372/2020	64 - BetaCoV/Japan/AI/I-004/2020	456
21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	40 - BetaCoV/Beijing/IV DC-BJ-005/2020	455
34 - BetaCoV/Shenzhen/SZTH-004/2020	59 - BetaCoV/France/IDF0373/2020	455
21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	62 - BetaCoV/Australia/NS WO 1/2020	454
59 - BetaCoV/France/IDF0373/2020	80 - BetaCoV/Taiwan/NTU01/2020	453
19 - BetaCov/Wuhan/WH04/2020	40 - BetaCoV/Beijing/IV DC-BJ-005/2020	452
62 - BetaCoV/Australia/NS WO 1/2020	65 - BetaCoV/Korea/KCDC03/2020	452
64 - BetaCoV/Japan/AI/I-004/2020	68 - BetaCoV/Singapore/2/2020	451
36 - BetaCoV/Zhejiang/WZ-02/2020	81 - BetaCoV/Singapore/3/2020	448
9 - BetaCoV/Wuhan/WIV07/2019	33 - BetaCoV/Shenzhen/SZTH-003/2020	446
5 - BetaCoV/Wuhan/WIV04/2019	9 - BetaCoV/Wuhan/WIV07/2019	445
6 - BetaCoV/Wuhan/WIV02/2019	33 - BetaCoV/Shenzhen/SZTH-003/2020	445
7 - BetaCoV/Wuhan/WIV05/2019	21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	444
8 - BetaCoV/Wuhan/WIV06/2019	17 - BetaCoV/China/WHU01/2020	443
18 - BetaCoV/China/WHU02/2020	36 - BetaCoV/Zhejiang/WZ-02/2020	443
21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	442
42 - BetaCoV/Hangzhou/HZCDC000 1/2020	58 - BetaCo V/France/IDF0372/2020	442
57 - BetaCoV/Guangdong/20SF201/2020	64 - BetaCoV/Japan/AI/I-004/2020	442
64 - BetaCoV/Japan/AI/I-004/2020	78 - BetaCov/France/IDF0626/2020	441
69 - BetaCoV/Germany/BavPat 1/2020	80 - BetaCoV/Taiwan/NTU01/2020	441
16 - BetaCov/Wuhan/WH03/2020	42 - BetaCoV/Hangzhou/HZCDC000 1/2020	439
8 - BetaCoV/Wuhan/WIV06/2019	45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	439
34 - BetaCoV/Shenzhen/SZTH-004/2020	64 - BetaCoV/Japan/AI/I-004/2020	439
44 - BetaCoV/Jiangsu/IVDC-JS-00 1/2020	62 - BetaCoV/Australia/NS WO 1/2020	437
64 - BetaCoV/Japan/AI/I-004/2020	81 - BetaCoV/Singapore/3/2020	437
32 - BetaCoV/Zhejiang/WZ-0 1/2020	45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	436
2 - BetaCov/Wuhan/WHO01/2019	16 - BetaCov/Wuhan/WH03/2020	434
9 - BetaCoV/Wuhan/WIV07/2019	45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	434
36 - BetaCoV/Zhejiang/WZ-02/2020	59 - BetaCoV/France/IDF0373/2020	433
6 - BetaCoV/Wuhan/WIV02/2019	79 - BetaCoV/Australia/QLD02/2020	432
70 - BetaCoV/Australia/QLD0O1/2020	81 - BetaCoV/Singapore/3/2020	432
16 - BetaCov/Wuhan/WH03/2020	45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	431
9 - BetaCoV/Wuhan/WIV07/2019	21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	430
6 - BetaCoV/Wuhan/WIV02/2019	16 - BetaCov/Wuhan/WH03/2020	428
21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	81 - BetaCoV/Singapore/3/2020	428
19 - BetaCov/Wuhan/WH04/2020	50 - BetaCoV/Guangdong/20SF174/2020	427
2 - BetaCov/Wuhan/WHO01/2019	33 - BetaCoV/Shenzhen/SZTH-003/2020	425
9 - BetaCoV/Wuhan/WIV07/2019	19 - BetaCov/Wuhan/WH04/2020	424
2 - BetaCov/Wuhan/WHO01/2019	45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	424
34 - BetaCoV/Shenzhen/SZTH-004/2020	62 - BetaCoV/Australia/NS WO 1/2020	423
44 - BetaCoV/Jiangsu/IVDC-JS-00 1/2020	58 - BetaCo V/France/IDF0372/2020	422
8 - BetaCoV/Wuhan/WIV06/2019	80 - BetaCoV/Taiwan/NTU01/2020	422
36 - BetaCoV/Zhejiang/WZ-02/2020	62 - BetaCoV/Australia/NS WO 1/2020	420
57 - BetaCoV/Guangdong/20SF201/2020	65 - BetaCoV/Korea/KCDC03/2020	420
77 - BetaCo V/France/IDF05 15/2020	82 - BetaCoV/Belgium/GHB-0302 1/2020	420
8 - BetaCoV/Wuhan/WIV06/2019	19 - BetaCov/Wuhan/WH04/2020	419
9 - BetaCoV/Wuhan/WIV07/2019	50 - BetaCoV/Guangdong/20SF174/2020	419
2 - BetaCov/Wuhan/WHO01/2019	21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	418
32 - BetaCoV/Zhejiang/WZ-0 1/2020	50 - BetaCoV/Guangdong/20SF174/2020	417
9 - BetaCoV/Wuhan/WIV07/2019	62 - BetaCoV/Australia/NS WO 1/2020	417
42 - BetaCoV/Hangzhou/HZCDC000 1/2020	80 - BetaCoV/Taiwan/NTU01/2020	413
6 - BetaCoV/Wuhan/WIV02/2019	32 - BetaCoV/Zhejiang/WZ-0 1/2020	412
16 - BetaCov/Wuhan/WH03/2020	65 - BetaCoV/Korea/KCDC03/2020	411
59 - BetaCoV/France/IDF0373/2020	79 - BetaCoV/Australia/QLD02/2020	410
7 - BetaCoV/Wuhan/WIV05/2019	36 - BetaCoV/Zhejiang/WZ-02/2020	409
8 - BetaCoV/Wuhan/WIV06/2019	32 - BetaCoV/Zhejiang/WZ-0 1/2020	408
7 - BetaCoV/Wuhan/WIV05/2019	32 - BetaCoV/Zhejiang/WZ-0 1/2020	407
21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	42 - BetaCoV/Hangzhou/HZCDC000 1/2020	407
36 - BetaCoV/Zhejiang/WZ-02/2020	79 - BetaCoV/Australia/QLD02/2020	407
7 - BetaCoV/Wuhan/WIV05/2019	33 - BetaCoV/Shenzhen/SZTH-003/2020	400
16 - BetaCov/Wuhan/WH03/2020	81 - BetaCoV/Singapore/3/2020	400

Table 6. Edge weight between distinct nucleotide sequences in the Transcendental Information Cascade we constructed (contd.).

Source sequence	Target sequence	Edge weight
9 - BetaCoV/Wuhan/WIV07/2019	36 - BetaCoV/Zhejiang/WZ-02/2020	399
8 - BetaCoV/Wuhan/WIV06/2019	62 - BetaCoV/Australia/NS WO 1/2020	399
8 - BetaCoV/Wuhan/WIV06/2019	81 - BetaCoV/Singapore/3/2020	398
16 - BetaCov/Wuhan/WH03/2020	62 - BetaCoV/Australia/NS WO 1/2020	397
2 - BetaCov/Wuhan/WHO01/2019	36 - BetaCoV/Zhejiang/WZ-02/2020	395
6 - BetaCoV/Wuhan/WIV02/2019	36 - BetaCoV/Zhejiang/WZ-02/2020	395
8 - BetaCoV/Wuhan/WIV06/2019	42 - BetaCoV/Hangzhou/HZCDC000 1/2020	393
7 - BetaCoV/Wuhan/WIV05/2019	50 - BetaCoV/Guangdong/20SF174/2020	393
42 - BetaCoV/Hangzhou/HZCDC000 1/2020	65 - BetaCoV/Korea/KCDC03/2020	393
55 - BetaCoV/Taiwan/2/2020	80 - BetaCoV/Taiwan/NTU01/2020	389
34 - BetaCoV/Shenzhen/SZTH-004/2020	79 - BetaCoV/Australia/QLD02/2020	382
21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	65 - BetaCoV/Korea/KCDC03/2020	380
6 - BetaCoV/Wuhan/WIV02/2019	50 - BetaCoV/Guangdong/20SF174/2020	376
9 - BetaCoV/Wuhan/WIV07/2019	64 - BetaCoV/Japan/AI/I-004/2020	375
16 - BetaCov/Wuhan/WH03/2020	79 - BetaCoV/Australia/QLD02/2020	374
21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	64 - BetaCoV/Japan/AI/I-004/2020	369
8 - BetaCoV/Wuhan/WIV06/2019	79 - BetaCoV/Australia/QLD02/2020	369
19 - BetaCov/Wuhan/WH04/2020	65 - BetaCoV/Korea/KCDC03/2020	367
2 - BetaCov/Wuhan/WHO01/2019	42 - BetaCoV/Hangzhou/HZCDC000 1/2020	360
19 - BetaCov/Wuhan/WH04/2020	80 - BetaCoV/Taiwan/NTU01/2020	360
8 - BetaCoV/Wuhan/WIV06/2019	65 - BetaCoV/Korea/KCDC03/2020	358
9 - BetaCoV/Wuhan/WIV07/2019	79 - BetaCoV/Australia/QLD02/2020	358
16 - BetaCov/Wuhan/WH03/2020	64 - BetaCoV/Japan/AI/I-004/2020	354
44 - BetaCoV/Jiangsu/IVDC-JS-00 1/2020	64 - BetaCoV/Japan/AI/I-004/2020	346
7 - BetaCoV/Wuhan/WIV05/2019	80 - BetaCoV/Taiwan/NTU01/2020	346
9 - BetaCoV/Wuhan/WIV07/2019	80 - BetaCoV/Taiwan/NTU01/2020	344
8 - BetaCoV/Wuhan/WIV06/2019	64 - BetaCoV/Japan/AI/I-004/2020	343
2 - BetaCov/Wuhan/WHO01/2019	80 - BetaCoV/Taiwan/NTU01/2020	342
21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	79 - BetaCoV/Australia/QLD02/2020	341
7 - BetaCoV/Wuhan/WIV05/2019	65 - BetaCoV/Korea/KCDC03/2020	339
2 - BetaCov/Wuhan/WHO01/2019	50 - BetaCoV/Guangdong/20SF174/2020	333
2 - BetaCov/Wuhan/WHO01/2019	62 - BetaCoV/Australia/NS WO 1/2020	331
9 - BetaCoV/Wuhan/WIV07/2019	81 - BetaCoV/Singapore/3/2020	331
76 - BetaCoV/USA/CA5/2020	81 - BetaCoV/Singapore/3/2020	328
6 - BetaCoV/Wuhan/WIV02/2019	65 - BetaCoV/Korea/KCDC03/2020	327
42 - BetaCoV/Hangzhou/HZCDC000 1/2020	81 - BetaCoV/Singapore/3/2020	325
2 - BetaCov/Wuhan/WHO01/2019	79 - BetaCoV/Australia/QLD02/2020	323
6 - BetaCoV/Wuhan/WIV02/2019	80 - BetaCoV/Taiwan/NTU01/2020	309
7 - BetaCoV/Wuhan/WIV05/2019	81 - BetaCoV/Singapore/3/2020	308
36 - BetaCoV/Zhejiang/WZ-02/2020	65 - BetaCoV/Korea/KCDC03/2020	295
19 - BetaCov/Wuhan/WH04/2020	81 - BetaCoV/Singapore/3/2020	290
2 - BetaCov/Wuhan/WHO01/2019	81 - BetaCoV/Singapore/3/2020	284
6 - BetaCoV/Wuhan/WIV02/2019	81 - BetaCoV/Singapore/3/2020	265
33 - BetaCoV/Shenzhen/SZTH-003/2020	36 - BetaCoV/Zhejiang/WZ-02/2020	256
18 - BetaCoV/China/WHU02/2020	34 - BetaCoV/Shenzhen/SZTH-004/2020	239
2 - BetaCov/Wuhan/WHO01/2019	64 - BetaCoV/Japan/AI/I-004/2020	238
47 - BetaCoV/Chonggqing/Y C0 1/2020	55 - BetaCoV/Taiwan/2/2020	237
55 - BetaCoV/Taiwan/2/2020	61 - BetaCoV/Chonggqing/ZX0 1/2020	225
32 - BetaCoV/Zhejiang/WZ-0 1/2020	34 - BetaCoV/Shenzhen/SZTH-004/2020	220
33 - BetaCoV/Shenzhen/SZTH-003/2020	35 - BetaCoV/Guangdong/20SF028/2020	207
60 - BetaCoV/Singapore/ 1/2020	62 - BetaCoV/Australia/NS WO 1/2020	204
2 - BetaCov/Wuhan/WHO01/2019	34 - BetaCoV/Shenzhen/SZTH-004/2020	201
9 - BetaCoV/Wuhan/WIV07/2019	34 - BetaCoV/Shenzhen/SZTH-004/2020	196
45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	79 - BetaCoV/Australia/QLD02/2020	194
47 - BetaCoV/Chonggqing/Y C0 1/2020	50 - BetaCoV/Guangdong/20SF174/2020	192
58 - BetaCo V/France/IDF0372/2020	61 - BetaCoV/Chonggqing/ZX0 1/2020	192
57 - BetaCoV/Guangdong/20SF201/2020	61 - BetaCoV/Chonggqing/ZX0 1/2020	185
45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	62 - BetaCoV/Australia/NS WO 1/2020	185
61 - BetaCoV/Chonggqing/ZX0 1/2020	81 - BetaCoV/Singapore/3/2020	184
59 - BetaCoV/France/IDF0373/2020	61 - BetaCoV/Chonggqing/ZX0 1/2020	183
47 - BetaCoV/Chonggqing/Y C0 1/2020	58 - BetaCo V/France/IDF0372/2020	179
33 - BetaCoV/Shenzhen/SZTH-003/2020	42 - BetaCoV/Hangzhou/HZCDC000 1/2020	178
72 - BetaCoV/England/02/2020	74 - BetaCoV/USA/CA3/2020	178
61 - BetaCoV/Chonggqing/ZX0 1/2020	78 - BetaCov/France/IDF0626/2020	178
33 - BetaCoV/Shenzhen/SZTH-003/2020	50 - BetaCoV/Guangdong/20SF174/2020	177
38 - BetaCoV/Guangdong/20SF040/2020	47 - BetaCoV/Chonggqing/Y C0 1/2020	175
33 - BetaCoV/Shenzhen/SZTH-003/2020	47 - BetaCoV/Chonggqing/Y C0 1/2020	174
47 - BetaCoV/Chonggqing/Y C0 1/2020	59 - BetaCoV/France/IDF0373/2020	171
7 - BetaCoV/Wuhan/WIV05/2019	34 - BetaCoV/Shenzhen/SZTH-004/2020	169
31 - BetaCoV/Sichuan/ITVDC-SC-00 1/2020	34 - BetaCoV/Shenzhen/SZTH-004/2020	165
45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	64 - BetaCoV/Japan/AI/I-004/2020	164
32 - BetaCoV/Zhejiang/WZ-0 1/2020	47 - BetaCoV/Chonggqing/Y C0 1/2020	162
34 - BetaCoV/Shenzhen/SZTH-004/2020	47 - BetaCoV/Chonggqing/Y C0 1/2020	162
45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	47 - BetaCoV/Chonggqing/Y C0 1/2020	160
19 - BetaCov/Wuhan/WH04/2020	47 - BetaCoV/Chonggqing/Y C0 1/2020	159
21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	47 - BetaCoV/Chonggqing/Y C0 1/2020	159
44 - BetaCoV/Jiangsu/IVDC-JS-00 1/2020	47 - BetaCoV/Chonggqing/Y C0 1/2020	159
21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	34 - BetaCoV/Shenzhen/SZTH-004/2020	158
61 - BetaCoV/Chonggqing/ZX0 1/2020	80 - BetaCoV/Taiwan/NTU01/2020	158
16 - BetaCov/Wuhan/WH03/2020	34 - BetaCoV/Shenzhen/SZTH-004/2020	157
61 - BetaCoV/Chonggqing/ZX0 1/2020	64 - BetaCoV/Japan/AI/I-004/2020	157
8 - BetaCoV/Wuhan/WIV06/2019	34 - BetaCoV/Shenzhen/SZTH-004/2020	155
36 - BetaCoV/Zhejiang/WZ-02/2020	47 - BetaCoV/Chonggqing/Y C0 1/2020	155
33 - BetaCoV/Shenzhen/SZTH-003/2020	40 - BetaCoV/Beijing/IV DC-BJ-005/2020	154
45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	59 - BetaCoV/France/IDF0373/2020	154
33 - BetaCoV/Shenzhen/SZTH-003/2020	80 - BetaCoV/Taiwan/NTU01/2020	154
33 - BetaCoV/Shenzhen/SZTH-003/2020	37 - BetaCoV/Yunnan/IVDC- Y N-003/2020	152
33 - BetaCoV/Shenzhen/SZTH-003/2020	45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	152
61 - BetaCoV/Chonggqing/ZX0 1/2020	68 - BetaCoV/Singapore/2/2020	150
45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	80 - BetaCoV/Taiwan/NTU01/2020	149
30 - BetaCoV/Guangdong/20SF025/2020	34 - BetaCoV/Shenzhen/SZTH-004/2020	148
33 - BetaCoV/Shenzhen/SZTH-003/2020	62 - BetaCoV/Australia/NS WO 1/2020	148
8 - BetaCoV/Wuhan/WIV06/2019	47 - BetaCoV/Chonggqing/Y C0 1/2020	147
16 - BetaCov/Wuhan/WH03/2020	47 - BetaCoV/Chonggqing/Y C0 1/2020	147
42 - BetaCoV/Hangzhou/HZCDC000 1/2020	47 - BetaCoV/Chonggqing/Y C0 1/2020	147
33 - BetaCoV/Shenzhen/SZTH-003/2020	64 - BetaCoV/Japan/AI/I-004/2020	147
19 - BetaCov/Wuhan/WH04/2020	34 - BetaCoV/Shenzhen/SZTH-004/2020	146
33 - BetaCoV/Shenzhen/SZTH-003/2020	65 - BetaCoV/Korea/KCDC03/2020	143
61 - BetaCoV/Chonggqing/ZX0 1/2020	65 - BetaCoV/Korea/KCDC03/2020	142

Table 7. Edge weight between distinct nucleotide sequences in the Transcendental Information Cascade we constructed (contd.).

Source sequence	Target sequence	Edge weight
61 - BetaCoV/Chonggqing/ZX0 1/2020	79 - BetaCoV/Australia/QLD02/2020	139
6 - BetaCoV/Wuhan/WIV02/2019	47 - BetaCoV/Chonggqing/Y C0 1/2020	138
45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	58 - BetaCo V/France/IDF0372/2020	138
33 - BetaCoV/Shenzhen/SZTH-003/2020	59 - BetaCoV/France/IDF0373/2020	133
9 - BetaCoV/Wuhan/WIV07/2019	47 - BetaCoV/Chonggqing/Y C0 1/2020	132
6 - BetaCoV/Wuhan/WIV02/2019	34 - BetaCoV/Shenzhen/SZTH-004/2020	129
2 - BetaCov/Wuhan/WHO01/2019	47 - BetaCoV/Chonggqing/Y C0 1/2020	124
45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	65 - BetaCoV/Korea/KCDC03/2020	120
36 - BetaCoV/Zhejiang/WZ-02/2020	55 - BetaCoV/Taiwan/2/2020	119
38 - BetaCoV/Guangdong/20SF040/2020	55 - BetaCoV/Taiwan/2/2020	118
33 - BetaCoV/Shenzhen/SZTH-003/2020	55 - BetaCoV/Taiwan/2/2020	114
33 - BetaCoV/Shenzhen/SZTH-003/2020	79 - BetaCoV/Australia/QLD02/2020	105
7 - BetaCoV/Wuhan/WIV05/2019	47 - BetaCoV/Chonggqing/Y C0 1/2020	103
21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	55 - BetaCoV/Taiwan/2/2020	96
60 - BetaCoV/Singapore/ 1/2020	66 - BetaCoV/USA/WA1-A12/2020	95
33 - BetaCoV/Shenzhen/SZTH-003/2020	81 - BetaCoV/Singapore/3/2020	95
8 - BetaCoV/Wuhan/WIV06/2019	55 - BetaCoV/Taiwan/2/2020	93
42 - BetaCoV/Hangzhou/HZCDC000 1/2020	55 - BetaCoV/Taiwan/2/2020	88
32 - BetaCoV/Zhejiang/WZ-0 1/2020	55 - BetaCoV/Taiwan/2/2020	84
16 - BetaCov/Wuhan/WH03/2020	55 - BetaCoV/Taiwan/2/2020	83
23 - BetaCoV/Jiangxi/IV DC-JX-002/2020	26 - BetaCoV/Shenzhen/SZTH-002/2020	72
6 - BetaCoV/Wuhan/WIV02/2019	55 - BetaCoV/Taiwan/2/2020	60
19 - BetaCov/Wuhan/WH04/2020	55 - BetaCoV/Taiwan/2/2020	59
2 - BetaCov/Wuhan/WHO01/2019	55 - BetaCoV/Taiwan/2/2020	58
9 - BetaCoV/Wuhan/WIV07/2019	55 - BetaCoV/Taiwan/2/2020	57
34 - BetaCoV/Shenzhen/SZTH-004/2020	55 - BetaCoV/Taiwan/2/2020	55
45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	68 - BetaCoV/Singapore/2/2020	53
7 - BetaCoV/Wuhan/WIV05/2019	55 - BetaCoV/Taiwan/2/2020	49
40 - BetaCoV/Beijing/IV DC-BJ-005/2020	68 - BetaCoV/Singapore/2/2020	47
45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	81 - BetaCoV/Singapore/3/2020	44
18 - BetaCoV/China/WHU02/2020	44 - BetaCoV/Jiangsu/IVDC-JS-00 1/2020	35
53 - BetaCo V/Foshan/20SF2 10/2020	57 - BetaCoV/Guangdong/20SF201/2020	35
40 - BetaCoV/Beijing/IV DC-BJ-005/2020	55 - BetaCoV/Taiwan/2/2020	34
56 - BetaCoV/USA/CA1/2020	66 - BetaCoV/USA/WA1-A12/2020	32
41 - BetaCoV/USA/WA 1/2020	46 - BetaCoV/USA/IL 1/2020	31
67 - BetaCoV/USA/W A 1-F6/2020	74 - BetaCoV/USA/CA3/2020	28
22 - BetaCoV/Shenzhen/HKU-SZ-005/2020	25 - BetaCoV/Shenzhen/SZTH-00 1/2020	24
67 - BetaCoV/USA/W A 1-F6/2020	73 - BetaCoV/Finland/1/2020	22
12 - BetaCoV/Wuhan/IPBCAMS-WH-03/2019	14 - BetaCoV/Wuhan/IV DC-HB-04/2020	21
26 - BetaCoV/Shenzhen/SZTH-002/2020	37 - BetaCoV/Yunnan/IVDC- Y N-003/2020	20
43 - BetaCoV/Shandong/IVDC-SD-00 1/2020	48 - BetaCoV/USA/CA2/2020	18
55 - BetaCoV/Taiwan/2/2020	77 - BetaCo V/France/IDF05 15/2020	18
15 - BetaCoV/Wuhan/IPBCAMS-WH-05/2020	23 - BetaCoV/Jiangxi/IV DC-JX-002/2020	14
39 - BetaCoV/Chongqing/IVDC-CQ-00 1/2020	43 - BetaCoV/Shandong/IVDC-SD-00 1/2020	13
28 - BetaCoV/Guangdong/20SFO0 13/2020	30 - BetaCoV/Guangdong/20SF025/2020	12
49 - BetaCoV/USA/AZ1/2020	60 - BetaCoV/Singapore/ 1/2020	12
14 - BetaCoV/Wuhan/IV DC-HB-04/2020	22 - BetaCoV/Shenzhen/HKU-SZ-005/2020	11
24 - BetaCoV/Nonthaburi/74/2020	29 - BetaCoV/Guangdong/20SFO0 14/2020	9
29 - BetaCoV/Guangdong/20SFO0 14/2020	35 - BetaCoV/Guangdong/20SF028/2020	9
31 - BetaCoV/Sichuan/ITVDC-SC-00 1/2020	56 - BetaCoV/USA/CA1/2020	9
19 - BetaCov/Wuhan/WH04/2020	63 - BetaCoV/Australia/VICO1/2020	9
73 - BetaCoV/Finland/1/2020	76 - BetaCoV/USA/CA5/2020	9
1 - BetaCoV/Wuhan/IPBCAMS-WH-01/2019	12 - BetaCoV/Wuhan/IPBCAMS-WH-03/2019	8
40 - BetaCoV/Beijing/IV DC-BJ-005/2020	43 - BetaCoV/Shandong/IVDC-SD-00 1/2020	8
56 - BetaCoV/USA/CA1/2020	61 - BetaCoV/Chonggqing/ZX0 1/2020	8
14 - BetaCoV/Wuhan/IV DC-HB-04/2020	33 - BetaCoV/Shenzhen/SZTH-003/2020	7
37 - BetaCoV/Yunnan/IVDC- Y N-003/2020	41 - BetaCoV/USA/WA 1/2020	7
43 - BetaCoV/Shandong/IVDC-SD-00 1/2020	47 - BetaCoV/Chonggqing/Y C0 1/2020	7
24 - BetaCoV/Nonthaburi/74/2020	58 - BetaCo V/France/IDF0372/2020	7
3 - BetaCoV/Wuhan/IV DC-HB-01/2019	5 - BetaCoV/Wuhan/WIV04/2019	6
13 - BetaCoV/Wuhan/IPBCAMS-WH-02/2019	15 - BetaCoV/Wuhan/IPBCAMS-WH-05/2020	6
47 - BetaCoV/Chonggqing/Y C0 1/2020	49 - BetaCoV/USA/AZ1/2020	6
50 - BetaCoV/Guangdong/20SF174/2020	52 - BetaCo V/Foshan/20SF207/2020	6
51 - BetaCoV/Guangzhou/20SF206/2020	53 - BetaCo V/Foshan/20SF2 10/2020	6
48 - BetaCoV/USA/CA2/2020	56 - BetaCoV/USA/CA1/2020	6
48 - BetaCoV/USA/CA2/2020	60 - BetaCoV/Singapore/ 1/2020	6
61 - BetaCoV/Chonggqing/ZX0 1/2020	66 - BetaCoV/USA/WA1-A12/2020	6
63 - BetaCoV/Australia/VICO1/2020	73 - BetaCoV/Finland/1/2020	6
72 - BetaCoV/England/02/2020	82 - BetaCoV/Belgium/GHB-0302 1/2020	6
75 - BetaCoV/USA/CA4/2020	82 - BetaCoV/Belgium/GHB-0302 1/2020	6
41 - BetaCoV/USA/WA 1/2020	47 - BetaCoV/Chonggqing/Y C0 1/2020	5
47 - BetaCoV/Chonggqing/Y C0 1/2020	51 - BetaCoV/Guangzhou/20SF206/2020	5
40 - BetaCoV/Beijing/IV DC-BJ-005/2020	62 - BetaCoV/Australia/NS WO 1/2020	5
38 - BetaCoV/Guangdong/20SF040/2020	78 - BetaCov/France/IDF0626/2020	5
34 - BetaCoV/Shenzhen/SZTH-004/2020	51 - BetaCoV/Guangzhou/20SF206/2020	4
56 - BetaCoV/USA/CA1/2020	63 - BetaCoV/Australia/VICO1/2020	4
58 - BetaCo V/France/IDF0372/2020	63 - BetaCoV/Australia/VICO1/2020	4
63 - BetaCoV/Australia/VICO1/2020	78 - BetaCov/France/IDF0626/2020	4
11 - BetaCoV/Wuhan/IPBCAMS-WH-04/2019	13 - BetaCoV/Wuhan/IPBCAMS-WH-02/2019	3
19 - BetaCov/Wuhan/WH04/2020	25 - BetaCoV/Shenzhen/SZTH-00 1/2020	3
22 - BetaCoV/Shenzhen/HKU-SZ-005/2020	26 - BetaCoV/Shenzhen/SZTH-002/2020	3
23 - BetaCoV/Jiangxi/IV DC-JX-002/2020	31 - BetaCoV/Sichuan/ITVDC-SC-00 1/2020	3
25 - BetaCoV/Shenzhen/SZTH-00 1/2020	33 - BetaCoV/Shenzhen/SZTH-003/2020	3
25 - BetaCoV/Shenzhen/SZTH-00 1/2020	39 - BetaCoV/Chongqing/IVDC-CQ-00 1/2020	3
26 - BetaCoV/Shenzhen/SZTH-002/2020	40 - BetaCoV/Beijing/IV DC-BJ-005/2020	3
26 - BetaCoV/Shenzhen/SZTH-002/2020	41 - BetaCoV/USA/WA 1/2020	3
31 - BetaCoV/Sichuan/ITVDC-SC-00 1/2020	41 - BetaCoV/USA/WA 1/2020	3
38 - BetaCoV/Guangdong/20SF040/2020	44 - BetaCoV/Jiangsu/IVDC-JS-00 1/2020	3
40 - BetaCoV/Beijing/IV DC-BJ-005/2020	47 - BetaCoV/Chonggqing/Y C0 1/2020	3
26 - BetaCoV/Shenzhen/SZTH-002/2020	49 - BetaCoV/USA/AZ1/2020	3
41 - BetaCoV/USA/WA 1/2020	49 - BetaCoV/USA/AZ1/2020	3
43 - BetaCoV/Shandong/IVDC-SD-00 1/2020	49 - BetaCoV/USA/AZ1/2020	3
46 - BetaCoV/USA/IL 1/2020	49 - BetaCoV/USA/AZ1/2020	3
52 - BetaCo V/Foshan/20SF207/2020	57 - BetaCoV/Guangdong/20SF201/2020	3
30 - BetaCoV/Guangdong/20SF025/2020	58 - BetaCo V/France/IDF0372/2020	3
2 - BetaCov/Wuhan/WHO01/2019	63 - BetaCoV/Australia/VICO1/2020	3
7 - BetaCoV/Wuhan/WIV05/2019	63 - BetaCoV/Australia/VICO1/2020	3
9 - BetaCoV/Wuhan/WIV07/2019	63 - BetaCoV/Australia/VICO1/2020	3
33 - BetaCoV/Shenzhen/SZTH-003/2020	63 - BetaCoV/Australia/VICO1/2020	3
45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	63 - BetaCoV/Australia/VICO1/2020	3
48 - BetaCoV/USA/CA2/2020	63 - BetaCoV/Australia/VICO1/2020	3
57 - BetaCoV/Guangdong/20SF201/2020	63 - BetaCoV/Australia/VICO1/2020	3

Table 8. Edge weight between distinct nucleotide sequences in the Transcendental Information Cascade we constructed (contd.).

Source sequence	Target sequence	Edge weight
47 - BetaCoV/Chonggqing/Y C0 1/2020	66 - BetaCoV/USA/WA1-A12/2020	3
63 - BetaCoV/Australia/VICO1/2020	69 - BetaCoV/Germany/BavPat 1/2020	3
63 - BetaCoV/Australia/VICO1/2020	71 - BetaCoV/England/01/2020	3
71 - BetaCoV/England/01/2020	73 - BetaCoV/Finland/1/2020	3
2 - BetaCov/Wuhan/WHO01/2019	22 - BetaCoV/Shenzhen/HKU-SZ-005/2020	2
16 - BetaCov/Wuhan/WH03/2020	25 - BetaCoV/Shenzhen/SZTH-00 1/2020	2
12 - BetaCoV/Wuhan/IPBCAMS-WH-03/2019	33 - BetaCoV/Shenzhen/SZTH-003/2020	2
22 - BetaCoV/Shenzhen/HKU-SZ-005/2020	36 - BetaCoV/Zhejiang/WZ-02/2020	2
23 - BetaCoV/Jiangxi/IV DC-JX-002/2020	39 - BetaCoV/Chongqing/IVDC-CQ-00 1/2020	2
2 - BetaCov/Wuhan/WHO01/2019	40 - BetaCoV/Beijing/IV DC-BJ-005/2020	2
18 - BetaCoV/China/WHU02/2020	42 - BetaCoV/Hangzhou/HZCDC000 1/2020	2
36 - BetaCoV/Zhejiang/WZ-02/2020	43 - BetaCoV/Shandong/IVDC-SD-00 1/2020	2
42 - BetaCoV/Hangzhou/HZCDC000 1/2020	46 - BetaCoV/USA/IL 1/2020	2
34 - BetaCoV/Shenzhen/SZTH-004/2020	48 - BetaCoV/USA/CA2/2020	2
45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	51 - BetaCoV/Guangzhou/20SF206/2020	2
40 - BetaCoV/Beijing/IV DC-BJ-005/2020	58 - BetaCo V/France/IDF0372/2020	2
2 - BetaCov/Wuhan/WHO01/2019	59 - BetaCoV/France/IDF0373/2020	2
49 - BetaCoV/USA/AZ1/2020	59 - BetaCoV/France/IDF0373/2020	2
43 - BetaCoV/Shandong/IVDC-SD-00 1/2020	62 - BetaCoV/Australia/NS WO 1/2020	2
8 - BetaCoV/Wuhan/WIV06/2019	63 - BetaCoV/Australia/VICO1/2020	2
36 - BetaCoV/Zhejiang/WZ-02/2020	63 - BetaCoV/Australia/VICO1/2020	2
55 - BetaCoV/Taiwan/2/2020	63 - BetaCoV/Australia/VICO1/2020	2
59 - BetaCoV/France/IDF0373/2020	63 - BetaCoV/Australia/VICO1/2020	2
63 - BetaCoV/Australia/VICO1/2020	68 - BetaCoV/Singapore/2/2020	2
19 - BetaCov/Wuhan/WH04/2020	70 - BetaCoV/Australia/QLD0O1/2020	2
21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	70 - BetaCoV/Australia/QLD0O1/2020	2
34 - BetaCoV/Shenzhen/SZTH-004/2020	70 - BetaCoV/Australia/QLD0O1/2020	2
36 - BetaCoV/Zhejiang/WZ-02/2020	70 - BetaCoV/Australia/QLD0O1/2020	2
45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	70 - BetaCoV/Australia/QLD0O1/2020	2
68 - BetaCoV/Singapore/2/2020	72 - BetaCoV/England/02/2020	2
65 - BetaCoV/Korea/KCDC03/2020	78 - BetaCov/France/IDF0626/2020	2
22 - BetaCoV/Shenzhen/HKU-SZ-005/2020	79 - BetaCoV/Australia/QLD02/2020	2
25 - BetaCoV/Shenzhen/SZTH-00 1/2020	79 - BetaCoV/Australia/QLD02/2020	2
56 - BetaCoV/USA/CA1/2020	79 - BetaCoV/Australia/QLD02/2020	2
63 - BetaCoV/Australia/VICO1/2020	79 - BetaCoV/Australia/QLD02/2020	2
48 - BetaCoV/USA/CA2/2020	80 - BetaCoV/Taiwan/NTU01/2020	2
52 - BetaCo V/Foshan/20SF207/2020	80 - BetaCoV/Taiwan/NTU01/2020	2
65 - BetaCoV/Korea/KCDC03/2020	80 - BetaCoV/Taiwan/NTU01/2020	2
67 - BetaCoV/USA/W A 1-F6/2020	81 - BetaCoV/Singapore/3/2020	2
5 - BetaCoV/Wuhan/WIV04/2019	12 - BetaCoV/Wuhan/IPBCAMS-WH-03/2019	1
8 - BetaCoV/Wuhan/WIV06/2019	13 - BetaCoV/Wuhan/IPBCAMS-WH-02/2019	1
2 - BetaCov/Wuhan/WHO01/2019	15 - BetaCoV/Wuhan/IPBCAMS-WH-05/2020	1
2 - BetaCov/Wuhan/WHO01/2019	20 - BetaCoV/Nonthaburi/6 1/2020	1
13 - BetaCoV/Wuhan/IPBCAMS-WH-02/2019	21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	1
6 - BetaCoV/Wuhan/WIV02/2019	22 - BetaCoV/Shenzhen/HKU-SZ-005/2020	1
20 - BetaCoV/Nonthaburi/6 1/2020	23 - BetaCoV/Jiangxi/IV DC-JX-002/2020	1
21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	23 - BetaCoV/Jiangxi/IV DC-JX-002/2020	1
6 - BetaCoV/Wuhan/WIV02/2019	25 - BetaCoV/Shenzhen/SZTH-00 1/2020	1
18 - BetaCoV/China/WHU02/2020	25 - BetaCoV/Shenzhen/SZTH-00 1/2020	1
24 - BetaCoV/Nonthaburi/74/2020	26 - BetaCoV/Shenzhen/SZTH-002/2020	1
16 - BetaCov/Wuhan/WH03/2020	27 - BetaCoV/Guangdong/20SFO0 12/2020	1
6 - BetaCoV/Wuhan/WIV02/2019	31 - BetaCoV/Sichuan/ITVDC-SC-00 1/2020	1
16 - BetaCov/Wuhan/WH03/2020	31 - BetaCoV/Sichuan/ITVDC-SC-00 1/2020	1
4 - BetaCoV/Wuhan/IV DC-HB-05/2019	32 - BetaCoV/Zhejiang/WZ-0 1/2020	1
25 - BetaCoV/Shenzhen/SZTH-00 1/2020	32 - BetaCoV/Zhejiang/WZ-0 1/2020	1
23 - BetaCoV/Jiangxi/IV DC-JX-002/2020	33 - BetaCoV/Shenzhen/SZTH-003/2020	1
26 - BetaCoV/Shenzhen/SZTH-002/2020	33 - BetaCoV/Shenzhen/SZTH-003/2020	1
29 - BetaCoV/Guangdong/20SFO0 14/2020	33 - BetaCoV/Shenzhen/SZTH-003/2020	1
12 - BetaCoV/Wuhan/IPBCAMS-WH-03/2019	34 - BetaCoV/Shenzhen/SZTH-004/2020	1
15 - BetaCoV/Wuhan/IPBCAMS-WH-05/2020	36 - BetaCoV/Zhejiang/WZ-02/2020	1
25 - BetaCoV/Shenzhen/SZTH-00 1/2020	36 - BetaCoV/Zhejiang/WZ-02/2020	1
30 - BetaCoV/Guangdong/20SF025/2020	36 - BetaCoV/Zhejiang/WZ-02/2020	1
19 - BetaCov/Wuhan/WH04/2020	37 - BetaCoV/Yunnan/IVDC- Y N-003/2020	1
33 - BetaCoV/Shenzhen/SZTH-003/2020	39 - BetaCoV/Chongqing/IVDC-CQ-00 1/2020	1
9 - BetaCoV/Wuhan/WIV07/2019	40 - BetaCoV/Beijing/IV DC-BJ-005/2020	1
25 - BetaCoV/Shenzhen/SZTH-00 1/2020	40 - BetaCoV/Beijing/IV DC-BJ-005/2020	1
25 - BetaCoV/Shenzhen/SZTH-00 1/2020	42 - BetaCoV/Hangzhou/HZCDC000 1/2020	1
6 - BetaCoV/Wuhan/WIV02/2019	43 - BetaCoV/Shandong/IVDC-SD-00 1/2020	1
8 - BetaCoV/Wuhan/WIV06/2019	43 - BetaCoV/Shandong/IVDC-SD-00 1/2020	1
16 - BetaCov/Wuhan/WH03/2020	43 - BetaCoV/Shandong/IVDC-SD-00 1/2020	1
38 - BetaCoV/Guangdong/20SF040/2020	43 - BetaCoV/Shandong/IVDC-SD-00 1/2020	1
9 - BetaCoV/Wuhan/WIV07/2019	44 - BetaCoV/Jiangsu/IVDC-JS-00 1/2020	1
41 - BetaCoV/USA/WA 1/2020	44 - BetaCoV/Jiangsu/IVDC-JS-00 1/2020	1
13 - BetaCoV/Wuhan/IPBCAMS-WH-02/2019	45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	1
23 - BetaCoV/Jiangxi/IV DC-JX-002/2020	45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	1
40 - BetaCoV/Beijing/IV DC-BJ-005/2020	45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	1
44 - BetaCoV/Jiangsu/IVDC-JS-00 1/2020	48 - BetaCoV/USA/CA2/2020	1
18 - BetaCoV/China/WHU02/2020	50 - BetaCoV/Guangdong/20SF174/2020	1
7 - BetaCoV/Wuhan/WIV05/2019	51 - BetaCoV/Guangzhou/20SF206/2020	1
16 - BetaCov/Wuhan/WH03/2020	51 - BetaCoV/Guangzhou/20SF206/2020	1
19 - BetaCov/Wuhan/WH04/2020	51 - BetaCoV/Guangzhou/20SF206/2020	1
36 - BetaCoV/Zhejiang/WZ-02/2020	51 - BetaCoV/Guangzhou/20SF206/2020	1
42 - BetaCoV/Hangzhou/HZCDC000 1/2020	51 - BetaCoV/Guangzhou/20SF206/2020	1
49 - BetaCoV/USA/AZ1/2020	51 - BetaCoV/Guangzhou/20SF206/2020	1
51 - BetaCoV/Guangzhou/20SF206/2020	55 - BetaCoV/Taiwan/2/2020	1
34 - BetaCoV/Shenzhen/SZTH-004/2020	56 - BetaCoV/USA/CA1/2020	1
53 - BetaCo V/Foshan/20SF2 10/2020	56 - BetaCoV/USA/CA1/2020	1
6 - BetaCoV/Wuhan/WIV02/2019	58 - BetaCo V/France/IDF0372/2020	1
43 - BetaCoV/Shandong/IVDC-SD-00 1/2020	58 - BetaCo V/France/IDF0372/2020	1
49 - BetaCoV/USA/AZ1/2020	58 - BetaCo V/France/IDF0372/2020	1
16 - BetaCov/Wuhan/WH03/2020	59 - BetaCoV/France/IDF0373/2020	1
9 - BetaCoV/Wuhan/WIV07/2019	60 - BetaCoV/Singapore/ 1/2020	1
48 - BetaCoV/USA/CA2/2020	61 - BetaCoV/Chonggqing/ZX0 1/2020	1
13 - BetaCoV/Wuhan/IPBCAMS-WH-02/2019	62 - BetaCoV/Australia/NS WO 1/2020	1
25 - BetaCoV/Shenzhen/SZTH-00 1/2020	62 - BetaCoV/Australia/NS WO 1/2020	1
6 - BetaCoV/Wuhan/WIV02/2019	63 - BetaCoV/Australia/VICO1/2020	1
16 - BetaCov/Wuhan/WH03/2020	63 - BetaCoV/Australia/VICO1/2020	1
42 - BetaCoV/Hangzhou/HZCDC000 1/2020	63 - BetaCoV/Australia/VICO1/2020	1
10 - BetaCoV/Wuhan/HBCDC-HB-01/2019	64 - BetaCoV/Japan/AI/I-004/2020	1
32 - BetaCoV/Zhejiang/WZ-0 1/2020	64 - BetaCoV/Japan/AI/I-004/2020	1
60 - BetaCoV/Singapore/ 1/2020	64 - BetaCoV/Japan/AI/I-004/2020	1
32 - BetaCoV/Zhejiang/WZ-0 1/2020	65 - BetaCoV/Korea/KCDC03/2020	1
40 - BetaCoV/Beijing/IV DC-BJ-005/2020	65 - BetaCoV/Korea/KCDC03/2020	1

Table 9. Edge weight between distinct nucleotide sequences in the Transcendental Information Cascade we constructed (contd.).

Source sequence	Target sequence	Edge weight
60 - BetaCoV/Singapore/ 1/2020	65 - BetaCoV/Korea/KCDC03/2020	1
58 - BetaCo V/France/IDF0372/2020	66 - BetaCoV/USA/WA1-A12/2020	1
62 - BetaCoV/Australia/NS WO 1/2020	66 - BetaCoV/USA/WA1-A12/2020	1
18 - BetaCoV/China/WHU02/2020	68 - BetaCoV/Singapore/2/2020	1
36 - BetaCoV/Zhejiang/WZ-02/2020	68 - BetaCoV/Singapore/2/2020	1
42 - BetaCoV/Hangzhou/HZCDC000 1/2020	68 - BetaCoV/Singapore/2/2020	1
2 - BetaCov/Wuhan/WHO01/2019	69 - BetaCoV/Germany/BavPat 1/2020	1
16 - BetaCov/Wuhan/WH03/2020	69 - BetaCoV/Germany/BavPat 1/2020	1
19 - BetaCov/Wuhan/WH04/2020	69 - BetaCoV/Germany/BavPat 1/2020	1
57 - BetaCoV/Guangdong/20SF201/2020	69 - BetaCoV/Germany/BavPat 1/2020	1
2 - BetaCov/Wuhan/WHO01/2019	70 - BetaCoV/Australia/QLD0O1/2020	1
7 - BetaCoV/Wuhan/WIV05/2019	70 - BetaCoV/Australia/QLD0O1/2020	1
8 - BetaCoV/Wuhan/WIV06/2019	70 - BetaCoV/Australia/QLD0O1/2020	1
33 - BetaCoV/Shenzhen/SZTH-003/2020	70 - BetaCoV/Australia/QLD0O1/2020	1
58 - BetaCo V/France/IDF0372/2020	70 - BetaCoV/Australia/QLD0O1/2020	1
61 - BetaCoV/Chonggqing/ZX0 1/2020	70 - BetaCoV/Australia/QLD0O1/2020	1
64 - BetaCoV/Japan/AI/I-004/2020	70 - BetaCoV/Australia/QLD0O1/2020	1
34 - BetaCoV/Shenzhen/SZTH-004/2020	71 - BetaCoV/England/01/2020	1
45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	71 - BetaCoV/England/01/2020	1
55 - BetaCoV/Taiwan/2/2020	71 - BetaCoV/England/01/2020	1
19 - BetaCov/Wuhan/WH04/2020	72 - BetaCoV/England/02/2020	1
21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	72 - BetaCoV/England/02/2020	1
67 - BetaCoV/USA/W A 1-F6/2020	72 - BetaCoV/England/02/2020	1
2 - BetaCov/Wuhan/WHO01/2019	74 - BetaCoV/USA/CA3/2020	1
57 - BetaCoV/Guangdong/20SF201/2020	76 - BetaCoV/USA/CA5/2020	1
19 - BetaCov/Wuhan/WH04/2020	77 - BetaCo V/France/IDF05 15/2020	1
58 - BetaCo V/France/IDF0372/2020	77 - BetaCo V/France/IDF05 15/2020	1
59 - BetaCoV/France/IDF0373/2020	77 - BetaCo V/France/IDF05 15/2020	1
61 - BetaCoV/Chonggqing/ZX0 1/2020	77 - BetaCo V/France/IDF05 15/2020	1
55 - BetaCoV/Taiwan/2/2020	78 - BetaCov/France/IDF0626/2020	1
14 - BetaCoV/Wuhan/IV DC-HB-04/2020	79 - BetaCoV/Australia/QLD02/2020	1
31 - BetaCoV/Sichuan/ITVDC-SC-00 1/2020	79 - BetaCoV/Australia/QLD02/2020	1
32 - BetaCoV/Zhejiang/WZ-0 1/2020	79 - BetaCoV/Australia/QLD02/2020	1
13 - BetaCoV/Wuhan/IPBCAMS-WH-02/2019	80 - BetaCoV/Taiwan/NTU01/2020	1
60 - BetaCoV/Singapore/ 1/2020	80 - BetaCoV/Taiwan/NTU01/2020	1

Table 10. Frequency of edge distances.

Edge distance	Frequency
1	801289
2	197353
3	166842
4	123821
5	92366
6	88539
7	87805
20	55715
10	51884
9	32851
22	27681
27	26443
24	24707
14	11886
26	7172
11	7013
13	6058
8	5205
15	3772
12	3304
17	3124
23	2893
16	2240
43	2168
25	2044
29	1968
21	1892
19	1811
28	1807
34	1682
31	1623
18	1601
45	1511
46	1445
30	1422
56	1402
44	1363
60	1344
72	1256
73	1176
38	1172
58	1159
36	1125
39	1071
37	1030
41	1011
55	961
63	911
57	899
59	836
48	832
47	732
71	713
35	685
74	617
42	616
62	529
64	505
53	477
49	474
40	468
33	459
54	405
65	401
61	363
70	358
32	351
78	342
77	323
79	284
75	265
51	4
50	2
67	2
52	1
68	1

Table 11. Cluster memberships of the nucleotide sequences (full TIC network).

Sequence ID	In-degree	Out-degree	Degree	Cluster
2 - BetaCov/Wuhan/WHO01/2019	1	34	35	0
6 - BetaCoV/Wuhan/WIV02/2019	2	30	32	0
7 - BetaCoV/Wuhan/WIV05/2019	3	26	29	0
8 - BetaCoV/Wuhan/WIV06/2019	4	26	30	0
9 - BetaCoV/Wuhan/WIV07/2019	5	25	30	0
16 - BetaCov/Wuhan/WH03/2020	7	28	35	0
19 - BetaCov/Wuhan/WH04/2020	9	27	36	0
21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	11	21	32	0
32 - BetaCoV/Zhejiang/WZ-0 1/2020	13	15	28	0
33 - BetaCoV/Shenzhen/SZTH-003/2020	18	20	38	0
34 - BetaCoV/Shenzhen/SZTH-004/2020	14	21	35	0
36 - BetaCoV/Zhejiang/WZ-02/2020	18	20	38	0
42 - BetaCoV/Hangzhou/HZCDC000 1/2020	17	18	35	0
45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	19	17	36	0
55 - BetaCoV/Taiwan/2/2020	21	16	37	0
59 - BetaCoV/France/IDF0373/2020	15	12	27	0
62 - BetaCoV/Australia/NS WO 1/2020	24	6	30	0
64 - BetaCoV/Japan/AI/I-004/2020	24	9	33	0
65 - BetaCoV/Korea/KCDC03/2020	25	6	31	0
69 - BetaCoV/Germany/BavPat 1/2020	10	7	17	0
70 - BetaCoV/Australia/QLD0O1/2020	16	6	22	0
79 - BetaCoV/Australia/QLD02/2020	30	3	33	0
80 - BetaCoV/Taiwan/NTU01/2020	29	2	31	0
81 - BetaCoV/Singapore/3/2020	26	1	27	0
1 - BetaCoV/Wuhan/IPBCAMS-WH-01/2019	0	3	3	1
3 - BetaCoV/Wuhan/IV DC-HB-01/2019	2	2	4	1
4 - BetaCoV/Wuhan/IV DC-HB-05/2019	1	2	3	1
5 - BetaCoV/Wuhan/WIV04/2019	2	7	9	1
11 - BetaCoV/Wuhan/IPBCAMS-WH-04/2019	6	2	8	1
12 - BetaCoV/Wuhan/IPBCAMS-WH-03/2019	3	4	7	1
13 - BetaCoV/Wuhan/IPBCAMS-WH-02/2019	3	6	9	1
14 - BetaCoV/Wuhan/IV DC-HB-04/2020	2	4	6	1
15 - BetaCoV/Wuhan/IPBCAMS-WH-05/2020	3	8	11	1
10 - BetaCoV/Wuhan/HBCDC-HB-01/2019	6	6	12	2
20 - BetaCoV/Nonthaburi/6 1/2020	6	4	10	2
24 - BetaCoV/Nonthaburi/74/2020	3	5	8	2
27 - BetaCoV/Guangdong/20SFO0 12/2020	3	1	4	2
28 - BetaCoV/Guangdong/20SFO0 13/2020	1	2	3	2
29 - BetaCoV/Guangdong/20SFO0 14/2020	2	3	5	2
30 - BetaCoV/Guangdong/20SF025/2020	2	7	9	2
35 - BetaCoV/Guangdong/20SF028/2020	6	3	9	2
38 - BetaCoV/Guangdong/20SF040/2020	3	11	14	2
58 - BetaCo V/France/IDF0372/2020	14	12	26	2
78 - BetaCov/France/IDF0626/2020	12	4	16	2
22 - BetaCoV/Shenzhen/HKU-SZ-005/2020	9	5	14	3
23 - BetaCoV/Jiangxi/IV DC-JX-002/2020	4	7	11	3
25 - BetaCoV/Shenzhen/SZTH-00 1/2020	7	9	16	3
26 - BetaCoV/Shenzhen/SZTH-002/2020	4	7	11	3
31 - BetaCoV/Sichuan/ITVDC-SC-00 1/2020	5	9	14	3
37 - BetaCoV/Yunnan/IVDC- Y N-003/2020	8	3	11	3
39 - BetaCoV/Chongqing/IVDC-CQ-00 1/2020	5	3	8	3
41 - BetaCoV/USA/WA 1/2020	5	6	11	3
43 - BetaCoV/Shandong/IVDC-SD-00 1/2020	9	8	17	3
46 - BetaCoV/USA/IL 1/2020	5	3	8	3
17 - BetaCoV/China/WHU01/2020	8	1	9	4
18 - BetaCoV/China/WHU02/2020	1	14	15	4
40 - BetaCoV/Beijing/IV DC-BJ-005/2020	13	11	24	4
44 - BetaCoV/Jiangsu/IVDC-JS-00 1/2020	7	12	19	4
68 - BetaCoV/Singapore/2/2020	16	5	21	4
77 - BetaCo V/France/IDF05 15/2020	9	5	14	4
47 - BetaCoV/Chonggqing/Y C0 1/2020	20	9	29	5
48 - BetaCoV/USA/CA2/2020	5	6	11	5
49 - BetaCoV/USA/AZ1/2020	6	7	13	5
56 - BetaCoV/USA/CA1/2020	7	8	15	5
60 - BetaCoV/Singapore/ 1/2020	7	7	14	5
61 - BetaCoV/Chonggqing/ZX0 1/2020	8	12	20	5
50 - BetaCoV/Guangdong/20SF174/2020	19	2	21	6
51 - BetaCoV/Guangzhou/20SF206/2020	10	3	13	6
52 - BetaCo V/Foshan/20SF207/2020	2	3	5	6
53 - BetaCo V/Foshan/20SF2 10/2020	2	3	5	6
54 - BetaCoV/Foshan/20SF21 1/2020	1	3	4	6
57 - BetaCoV/Guangdong/20SF201/2020	5	14	19	6
63 - BetaCoV/Australia/VICO1/2020	20	9	29	7
66 - BetaCoV/USA/WA1-A12/2020	9	1	10	7
67 - BetaCoV/USA/W A 1-F6/2020	1	8	9	7
71 - BetaCoV/England/01/2020	8	2	10	7
72 - BetaCoV/England/02/2020	5	3	8	7
73 - BetaCoV/Finland/1/2020	4	2	6	7
74 - BetaCoV/USA/CA3/2020	4	1	5	7
75 - BetaCoV/USA/CA4/2020	1	2	3	7
76 - BetaCoV/USA/CA5/2020	3	6	9	7
82 - BetaCoV/Belgium/GHB-0302 1/2020	8	0	8	7

Table 12. Inter-cluster similarities for the full TIC network.

Inter-cluster pair	Avg. similarity	SD	Min. similarity	Max. similarity
0-1	0.267773	0.013962	0.252325	0.293298
0-2	0.265648	0.012247	0.251072	0.288222
0-3	0.267719	0.013965	0.252326	0.293298
0-4	0.267501	0.021119	0.250904	0.358635
0-5	0.267639	0.013011	0.252337	0.293264
0-6	0.265093	0.013211	0.251181	0.288327
0-7	0.267556	0.013985	0.250745	0.293466
1-2	0.259499	0.000047	0.259407	0.259605
1-3	0.999513	0.000290	0.998796	0.999900
1-4	0.269435	0.000147	0.269120	0.269655
1-5	0.927233	0.103628	0.781755	0.999966
1-6	0.258528	0.000033	0.258454	0.258598
1-7	0.998823	0.001846	0.993938	0.999933
2-3	0.259472	0.000053	0.259373	0.259572
2-4	0.255754	0.000079	0.255587	0.255887
2-5	0.260785	0.001855	0.259407	0.263405
2-6	0.284333	0.000043	0.284259	0.284454
2-7	0.259330	0.000421	0.258067	0.259682
3-4	0.269369	0.000184	0.268965	0.269823
3-5	0.926970	0.103499	0.781540	0.999967
3-6	0.258482	0.000049	0.258387	0.258598
3-7	0.998632	0.001816	0.993235	1.000000
4-5	0.268894	0.000682	0.267715	0.269603
4-6	0.263907	0.000187	0.263414	0.264057
4-7	0.269143	0.000600	0.267290	0.269928
5-6	0.260599	0.002943	0.258521	0.264821
5-7	0.926460	0.103206	0.779396	0.999900
6-7	0.258383	0.000525	0.256844	0.258889

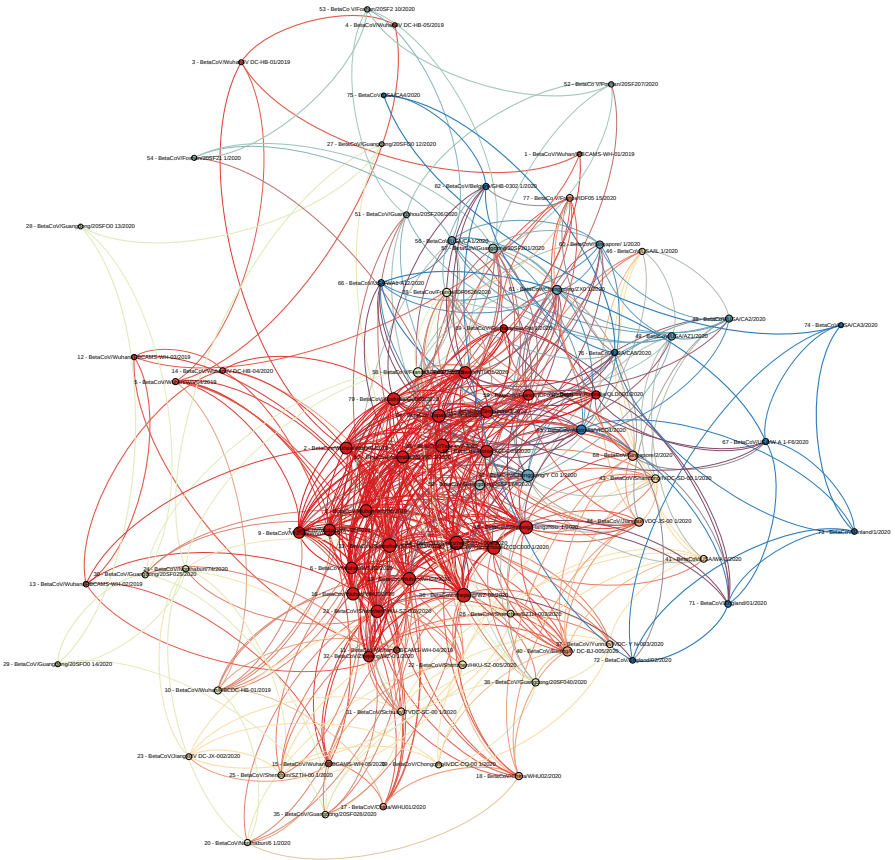


Figure 6. +1 reading frame network.

Table 13. Cluster memberships of the nucleotide sequences (network for +1 reading frames).

Sequence ID	In-degree	Out-degree	Degree	Cluster
2 - BetaCov/Wuhan/WHO01/2019	1	27	28	0
6 - BetaCoV/Wuhan/WIV02/2019	2	25	27	0
7 - BetaCoV/Wuhan/WIV05/2019	3	24	27	0
8 - BetaCoV/Wuhan/WIV06/2019	4	24	28	0
9 - BetaCoV/Wuhan/WIV07/2019	5	21	26	0
16 - BetaCov/Wuhan/WH03/2020	7	23	30	0
19 - BetaCov/Wuhan/WH04/2020	9	21	30	0
21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	11	19	30	0
32 - BetaCoV/Zhejiang/WZ-0 1/2020	11	12	23	0
33 - BetaCoV/Shenzhen/SZTH-003/2020	15	19	34	0
34 - BetaCoV/Shenzhen/SZTH-004/2020	13	20	33	0
36 - BetaCoV/Zhejiang/WZ-02/2020	16	18	34	0
42 - BetaCoV/Hangzhou/HZCDC000 1/2020	16	15	31	0
45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	17	15	32	0
55 - BetaCoV/Taiwan/2/2020	20	14	34	0
59 - BetaCoV/France/IDF0373/2020	13	10	23	0
62 - BetaCoV/Australia/NS WO 1/2020	22	6	28	0
64 - BetaCoV/Japan/AI/I-004/2020	22	9	31	0
65 - BetaCoV/Korea/KCDC03/2020	24	5	29	0
69 - BetaCoV/Germany/BavPat 1/2020	6	7	13	0
70 - BetaCoV/Australia/QLD0O1/2020	9	6	15	0
79 - BetaCoV/Australia/QLD02/2020	27	3	30	0
80 - BetaCoV/Taiwan/NTU01/2020	26	2	28	0
81 - BetaCoV/Singapore/3/2020	26	1	27	0
1 - BetaCoV/Wuhan/IPBCAMS-WH-01/2019	0	3	3	1
3 - BetaCoV/Wuhan/IV DC-HB-01/2019	2	2	4	1
4 - BetaCoV/Wuhan/IV DC-HB-05/2019	1	1	2	1
5 - BetaCoV/Wuhan/WIV04/2019	2	6	8	1
11 - BetaCoV/Wuhan/IPBCAMS-WH-04/2019	6	2	8	1
12 - BetaCoV/Wuhan/IPBCAMS-WH-03/2019	2	3	5	1
13 - BetaCoV/Wuhan/IPBCAMS-WH-02/2019	2	4	6	1
14 - BetaCoV/Wuhan/IV DC-HB-04/2020	2	4	6	1
15 - BetaCoV/Wuhan/IPBCAMS-WH-05/2020	2	7	9	1
17 - BetaCoV/China/WHU01/2020	8	1	9	2
18 - BetaCoV/China/WHU02/2020	1	11	12	2
40 - BetaCoV/Beijing/IV DC-BJ-005/2020	10	9	19	2
44 - BetaCoV/Jiangsu/IVDC-JS-00 1/2020	4	12	16	2
68 - BetaCoV/Singapore/2/2020	14	5	19	2
77 - BetaCo V/France/IDF05 15/2020	5	5	10	2
22 - BetaCoV/Shenzhen/HKU-SZ-005/2020	8	5	13	3
23 - BetaCoV/Jiangxi/IV DC-JX-002/2020	2	5	7	3
25 - BetaCoV/Shenzhen/SZTH-00 1/2020	4	5	9	3
26 - BetaCoV/Shenzhen/SZTH-002/2020	4	6	10	3
31 - BetaCoV/Sichuan/ITVDC-SC-00 1/2020	3	8	11	3
37 - BetaCoV/Yunnan/IVDC- Y N-003/2020	7	3	10	3
39 - BetaCoV/Chongqing/IVDC-CQ-00 1/2020	4	3	7	3
41 - BetaCoV/USA/WA 1/2020	5	5	10	3
43 - BetaCoV/Shandong/IVDC-SD-00 1/2020	7	6	13	3
46 - BetaCoV/USA/IL 1/2020	5	3	8	3
10 - BetaCoV/Wuhan/HBCDC-HB-01/2019	6	5	11	4
20 - BetaCoV/Nonthaburi/6 1/2020	5	3	8	4
24 - BetaCoV/Nonthaburi/74/2020	3	5	8	4
27 - BetaCoV/Guangdong/20SFO0 12/2020	2	1	3	4
28 - BetaCoV/Guangdong/20SFO0 13/2020	1	2	3	4
29 - BetaCoV/Guangdong/20SFO0 14/2020	2	2	4	4
30 - BetaCoV/Guangdong/20SF025/2020	2	6	8	4
35 - BetaCoV/Guangdong/20SF028/2020	6	3	9	4
38 - BetaCoV/Guangdong/20SF040/2020	3	9	12	4
58 - BetaCo V/France/IDF0372/2020	11	8	19	4
78 - BetaCov/France/IDF0626/2020	11	4	15	4
50 - BetaCoV/Guangdong/20SF174/2020	18	2	20	5
51 - BetaCoV/Guangzhou/20SF206/2020	5	2	7	5
52 - BetaCo V/Foshan/20SF207/2020	2	3	5	5
53 - BetaCo V/Foshan/20SF2 10/2020	2	3	5	5
54 - BetaCoV/Foshan/20SF21 1/2020	1	3	4	5
57 - BetaCoV/Guangdong/20SF201/2020	5	12	17	5
47 - BetaCoV/Chonggqing/Y C0 1/2020	19	9	28	6
48 - BetaCoV/USA/CA2/2020	5	6	11	6
49 - BetaCoV/USA/AZ1/2020	6	6	12	6
56 - BetaCoV/USA/CA1/2020	6	8	14	6
60 - BetaCoV/Singapore/ 1/2020	6	6	12	6
61 - BetaCoV/Chonggqing/ZX0 1/2020	8	10	18	6
63 - BetaCoV/Australia/VICO1/2020	12	7	19	7
66 - BetaCoV/USA/WA1-A12/2020	8	1	9	7
67 - BetaCoV/USA/W A 1-F6/2020	1	7	8	7
71 - BetaCoV/England/01/2020	7	2	9	7
72 - BetaCoV/England/02/2020	3	3	6	7
73 - BetaCoV/Finland/1/2020	4	2	6	7
74 - BetaCoV/USA/CA3/2020	3	1	4	7
75 - BetaCoV/USA/CA4/2020	1	2	3	7
76 - BetaCoV/USA/CA5/2020	2	6	8	7
82 - BetaCoV/Belgium/GHB-0302 1/2020	8	0	8	7

Table 14. Intra-cluster similarities (network for +1 reading frames).

Cluster	Avg. similarity	SD	Min. similarity	Max. similarity	Cluster size
0	0.277353	0.088247	0.250620	0.999866	24
1	0.999730	0.000222	0.999231	1.000000	9
2	0.998768	0.001345	0.996387	1.000000	6
3	0.999385	0.000371	0.998461	0.999933	10
4	0.999915	0.000048	0.999832	1.000000	11
5	0.999926	0.000036	0.999866	1.000000	6
6	0.883701	0.112398	0.781976	0.999899	6
7	0.997900	0.002419	0.991158	1.000000	10

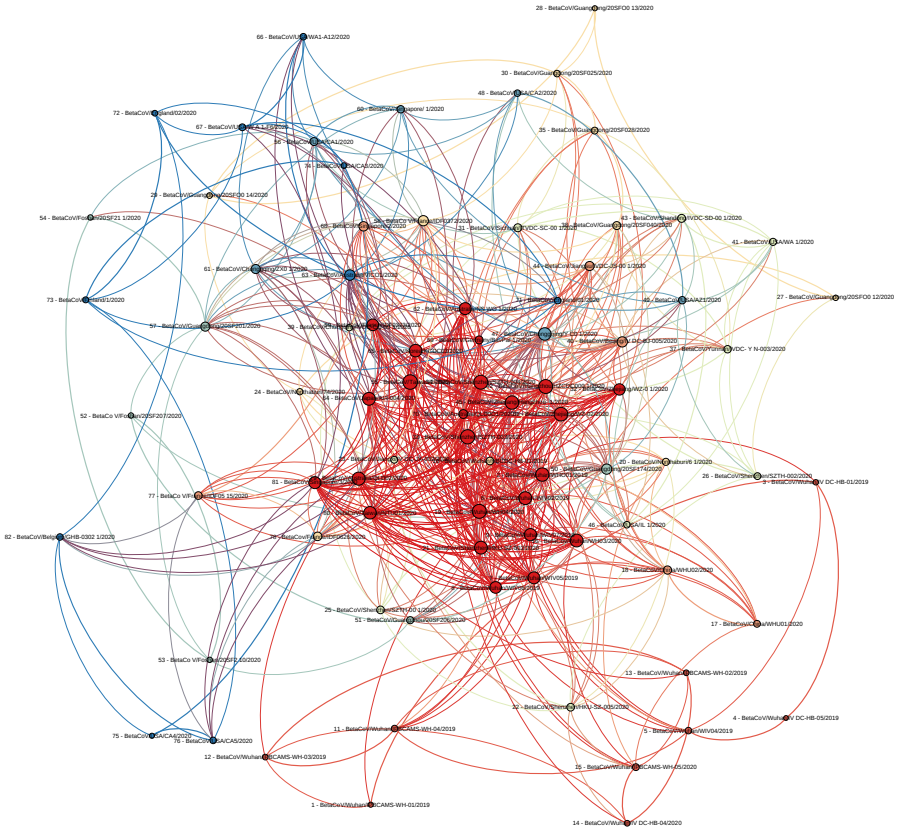


Figure 7. +2 reading frame network.

Table 15. Cluster memberships of the nucleotide sequences (network for +2 reading frames).

Sequence ID	In-degree	Out-degree	Degree	Cluster
2 - BetaCov/Wuhan/WHO01/2019	1	31	32	0
6 - BetaCoV/Wuhan/WIV02/2019	2	28	30	0
7 - BetaCoV/Wuhan/WIV05/2019	3	24	27	0
8 - BetaCoV/Wuhan/WIV06/2019	4	22	26	0
9 - BetaCoV/Wuhan/WIV07/2019	5	23	28	0
16 - BetaCov/Wuhan/WH03/2020	7	23	30	0
19 - BetaCov/Wuhan/WH04/2020	9	25	34	0
21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	10	20	30	0
32 - BetaCoV/Zhejiang/WZ-0 1/2020	11	14	25	0
33 - BetaCoV/Shenzhen/SZTH-003/2020	16	19	35	0
34 - BetaCoV/Shenzhen/SZTH-004/2020	14	20	34	0
36 - BetaCoV/Zhejiang/WZ-02/2020	14	19	33	0
42 - BetaCoV/Hangzhou/HZCDC000 1/2020	16	18	34	0
45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	16	16	32	0
55 - BetaCoV/Taiwan/2/2020	21	15	36	0
59 - BetaCoV/France/IDF0373/2020	14	12	26	0
62 - BetaCoV/Australia/NS WO 1/2020	22	5	27	0
64 - BetaCoV/Japan/AI/I-004/2020	22	8	30	0
65 - BetaCoV/Korea/KCDC03/2020	23	6	29	0
69 - BetaCoV/Germany/BavPat 1/2020	6	7	13	0
70 - BetaCoV/Australia/QLD0O1/2020	10	6	16	0
79 - BetaCoV/Australia/QLD02/2020	28	3	31	0
80 - BetaCoV/Taiwan/NTU01/2020	27	2	29	0
81 - BetaCoV/Singapore/3/2020	26	1	27	0
1 - BetaCoV/Wuhan/IPBCAMS-WH-01/2019	0	3	3	1
3 - BetaCoV/Wuhan/IV DC-HB-01/2019	2	2	4	1
4 - BetaCoV/Wuhan/IV DC-HB-05/2019	1	1	2	1
5 - BetaCoV/Wuhan/WIV04/2019	2	6	8	1
11 - BetaCoV/Wuhan/IPBCAMS-WH-04/2019	6	2	8	1
12 - BetaCoV/Wuhan/IPBCAMS-WH-03/2019	2	3	5	1
13 - BetaCoV/Wuhan/IPBCAMS-WH-02/2019	2	3	5	1
14 - BetaCoV/Wuhan/IV DC-HB-04/2020	2	3	5	1
15 - BetaCoV/Wuhan/IPBCAMS-WH-05/2020	2	7	9	1
17 - BetaCoV/China/WHU01/2020	8	1	9	2
18 - BetaCoV/China/WHU02/2020	1	13	14	2
40 - BetaCoV/Beijing/IV DC-BJ-005/2020	12	9	21	2
44 - BetaCoV/Jiangsu/IVDC-JS-00 1/2020	6	11	17	2
68 - BetaCoV/Singapore/2/2020	14	4	18	2
77 - BetaCo V/France/IDF05 15/2020	7	5	12	2
10 - BetaCoV/Wuhan/HBCDC-HB-01/2019	6	6	12	3
20 - BetaCoV/Nonthaburi/6 1/2020	6	4	10	3
24 - BetaCoV/Nonthaburi/74/2020	3	4	7	3
27 - BetaCoV/Guangdong/20SFO0 12/2020	3	1	4	3
28 - BetaCoV/Guangdong/20SFO0 13/2020	1	2	3	3
29 - BetaCoV/Guangdong/20SFO0 14/2020	2	3	5	3
30 - BetaCoV/Guangdong/20SF025/2020	2	6	8	3
35 - BetaCoV/Guangdong/20SF028/2020	6	3	9	3
38 - BetaCoV/Guangdong/20SF040/2020	3	10	13	3
58 - BetaCo V/France/IDF0372/2020	12	9	21	3
78 - BetaCov/France/IDF0626/2020	11	4	15	3
22 - BetaCoV/Shenzhen/HKU-SZ-005/2020	8	4	12	4
23 - BetaCoV/Jiangxi/IV DC-JX-002/2020	4	5	9	4
25 - BetaCoV/Shenzhen/SZTH-00 1/2020	7	5	12	4
26 - BetaCoV/Shenzhen/SZTH-002/2020	3	6	9	4
31 - BetaCoV/Sichuan/ITVDC-SC-00 1/2020	4	9	13	4
37 - BetaCoV/Yunnan/IVDC- Y N-003/2020	8	3	11	4
39 - BetaCoV/Chongqing/IVDC-CQ-00 1/2020	4	3	7	4
41 - BetaCoV/USA/WA 1/2020	5	5	10	4
43 - BetaCoV/Shandong/IVDC-SD-00 1/2020	6	7	13	4
46 - BetaCoV/USA/IL 1/2020	5	3	8	4
50 - BetaCoV/Guangdong/20SF174/2020	19	2	21	5
51 - BetaCoV/Guangzhou/20SF206/2020	7	3	10	5
52 - BetaCo V/Foshan/20SF207/2020	2	2	4	5
53 - BetaCo V/Foshan/20SF2 10/2020	2	2	4	5
54 - BetaCoV/Foshan/20SF21 1/2020	1	3	4	5
57 - BetaCoV/Guangdong/20SF201/2020	5	12	17	5
47 - BetaCoV/Chonggqing/Y C0 1/2020	20	9	29	6
48 - BetaCoV/USA/CA2/2020	4	4	8	6
49 - BetaCoV/USA/AZ1/2020	6	5	11	6
56 - BetaCoV/USA/CA1/2020	6	7	13	6
60 - BetaCoV/Singapore/ 1/2020	6	5	11	6
61 - BetaCoV/Chonggqing/ZX0 1/2020	7	10	17	6
63 - BetaCoV/Australia/VICO1/2020	15	7	22	7
66 - BetaCoV/USA/WA1-A12/2020	7	1	8	7
67 - BetaCoV/USA/W A 1-F6/2020	1	8	9	7
71 - BetaCoV/England/01/2020	6	2	8	7
72 - BetaCoV/England/02/2020	2	3	5	7
73 - BetaCoV/Finland/1/2020	4	2	6	7
74 - BetaCoV/USA/CA3/2020	4	1	5	7
75 - BetaCoV/USA/CA4/2020	1	2	3	7
76 - BetaCoV/USA/CA5/2020	2	6	8	7
82 - BetaCoV/Belgium/GHB-0302 1/2020	8	0	8	7

Table 16. Intra-cluster similarities (network for +2 reading frames).

Cluster	Avg. similarity	SD	Min. similarity	Max. similarity	Cluster size
0	0.277353	0.088247	0.250620	0.999866	24
1	0.999730	0.000222	0.999231	1.000000	9
2	0.998768	0.001345	0.996387	1.000000	6
3	0.999915	0.000048	0.999832	1.000000	11
4	0.999385	0.000371	0.998461	0.999933	10
5	0.999926	0.000036	0.999866	1.000000	6
6	0.883701	0.112398	0.781976	0.999899	6
7	0.997900	0.002419	0.991158	1.000000	10

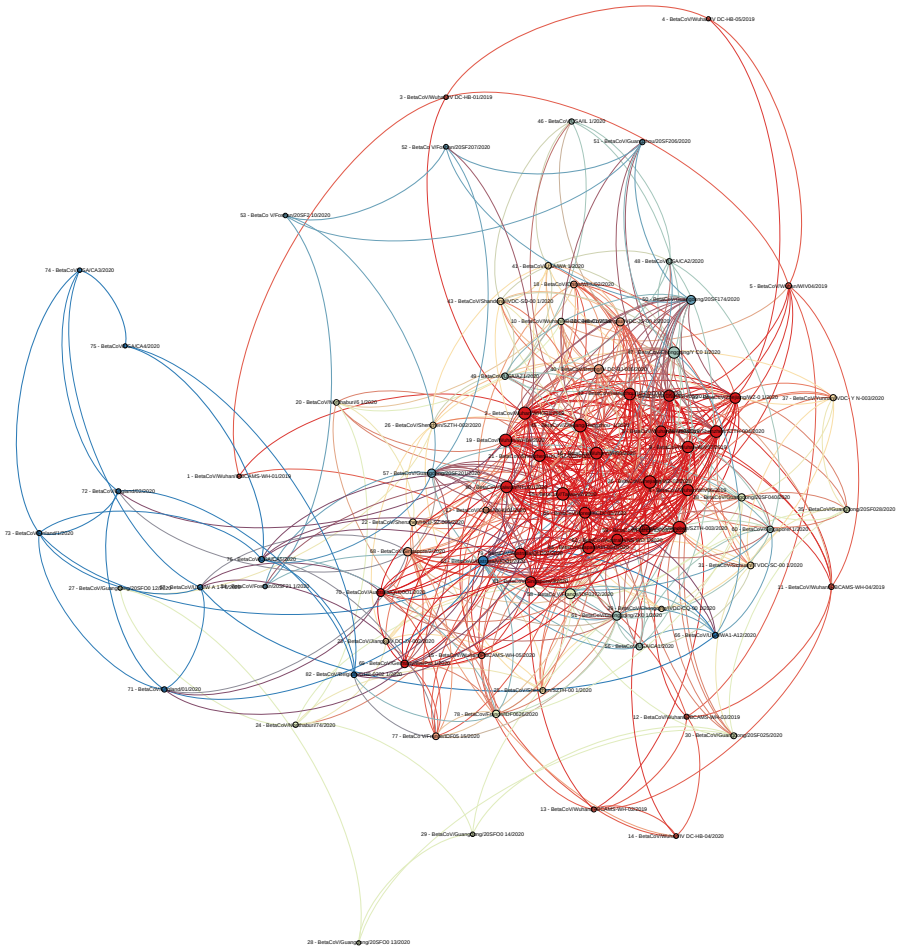


Figure 8. +3 reading frame network.

Table 17. Cluster memberships of the nucleotide sequences (network for +3 reading frames).

Sequence ID	In-degree	Out-degree	Degree	Cluster
2 - BetaCov/Wuhan/WHO01/2019	1	31	32	0
6 - BetaCoV/Wuhan/WIV02/2019	2	25	27	0
7 - BetaCoV/Wuhan/WIV05/2019	3	25	28	0
8 - BetaCoV/Wuhan/WIV06/2019	4	24	28	0
9 - BetaCoV/Wuhan/WIV07/2019	5	24	29	0
16 - BetaCov/Wuhan/WH03/2020	7	23	30	0
19 - BetaCov/Wuhan/WH04/2020	9	23	32	0
21 - BetaCoV/Shenzhen/HKU-SZ-002/2020	10	19	29	0
32 - BetaCoV/Zhejiang/WZ-0 1/2020	13	13	26	0
33 - BetaCoV/Shenzhen/SZTH-003/2020	16	18	34	0
34 - BetaCoV/Shenzhen/SZTH-004/2020	13	17	30	0
36 - BetaCoV/Zhejiang/WZ-02/2020	17	16	33	0
42 - BetaCoV/Hangzhou/HZCDC000 1/2020	16	14	30	0
45 - BetaCoV/Zhejiang/Hangzhou- 1/2020	18	15	33	0
55 - BetaCoV/Taiwan/2/2020	20	13	33	0
59 - BetaCoV/France/IDF0373/2020	14	10	24	0
62 - BetaCoV/Australia/NS WO 1/2020	22	5	27	0
64 - BetaCoV/Japan/AI/I-004/2020	22	8	30	0
65 - BetaCoV/Korea/KCDC03/2020	22	5	27	0
69 - BetaCoV/Germany/BavPat 1/2020	8	7	15	0
70 - BetaCoV/Australia/QLD0O1/2020	10	6	16	0
79 - BetaCoV/Australia/QLD02/2020	24	3	27	0
80 - BetaCoV/Taiwan/NTU01/2020	27	2	29	0
81 - BetaCoV/Singapore/3/2020	25	1	26	0
1 - BetaCoV/Wuhan/IPBCAMS-WH-01/2019	0	3	3	1
3 - BetaCoV/Wuhan/IV DC-HB-01/2019	2	2	4	1
4 - BetaCoV/Wuhan/IV DC-HB-05/2019	1	2	3	1
5 - BetaCoV/Wuhan/WIV04/2019	2	7	9	1
11 - BetaCoV/Wuhan/IPBCAMS-WH-04/2019	6	2	8	1
12 - BetaCoV/Wuhan/IPBCAMS-WH-03/2019	3	3	6	1
13 - BetaCoV/Wuhan/IPBCAMS-WH-02/2019	3	3	6	1
14 - BetaCoV/Wuhan/IV DC-HB-04/2020	2	3	5	1
15 - BetaCoV/Wuhan/IPBCAMS-WH-05/2020	3	8	11	1
17 - BetaCoV/China/WHU01/2020	8	1	9	2
18 - BetaCoV/China/WHU02/2020	1	11	12	2
40 - BetaCoV/Beijing/IV DC-BJ-005/2020	12	9	21	2
44 - BetaCoV/Jiangsu/IVDC-JS-00 1/2020	6	11	17	2
68 - BetaCoV/Singapore/2/2020	13	5	18	2
77 - BetaCo V/France/IDF05 15/2020	7	5	12	2
22 - BetaCoV/Shenzhen/HKU-SZ-005/2020	8	4	12	3
23 - BetaCoV/Jiangxi/IV DC-JX-002/2020	2	6	8	3
25 - BetaCoV/Shenzhen/SZTH-00 1/2020	4	5	9	3
26 - BetaCoV/Shenzhen/SZTH-002/2020	3	7	10	3
31 - BetaCoV/Sichuan/ITVDC-SC-00 1/2020	4	8	12	3
37 - BetaCoV/Yunnan/IVDC- Y N-003/2020	7	3	10	3
39 - BetaCoV/Chongqing/IVDC-CQ-00 1/2020	4	3	7	3
41 - BetaCoV/USA/WA 1/2020	5	6	11	3
43 - BetaCoV/Shandong/IVDC-SD-00 1/2020	5	7	12	3
10 - BetaCoV/Wuhan/HBCDC-HB-01/2019	6	5	11	4
20 - BetaCoV/Nonthaburi/6 1/2020	5	3	8	4
24 - BetaCoV/Nonthaburi/74/2020	3	4	7	4
27 - BetaCoV/Guangdong/20SFO0 12/2020	2	1	3	4
28 - BetaCoV/Guangdong/20SFO0 13/2020	1	2	3	4
29 - BetaCoV/Guangdong/20SFO0 14/2020	2	2	4	4
30 - BetaCoV/Guangdong/20SF025/2020	2	7	9	4
35 - BetaCoV/Guangdong/20SF028/2020	6	3	9	4
38 - BetaCoV/Guangdong/20SF040/2020	3	11	14	4
58 - BetaCo V/France/IDF0372/2020	12	12	24	4
78 - BetaCov/France/IDF0626/2020	10	4	14	4
46 - BetaCoV/USA/IL 1/2020	4	3	7	5
47 - BetaCoV/Chonggqing/Y C0 1/2020	20	9	29	5
48 - BetaCoV/USA/CA2/2020	3	5	8	5
49 - BetaCoV/USA/AZ1/2020	6	5	11	5
56 - BetaCoV/USA/CA1/2020	5	7	12	5
60 - BetaCoV/Singapore/ 1/2020	7	4	11	5
61 - BetaCoV/Chonggqing/ZX0 1/2020	7	12	19	5
50 - BetaCoV/Guangdong/20SF174/2020	18	2	20	6
51 - BetaCoV/Guangzhou/20SF206/2020	5	2	7	6
52 - BetaCo V/Foshan/20SF207/2020	2	3	5	6
53 - BetaCo V/Foshan/20SF2 10/2020	2	2	4	6
54 - BetaCoV/Foshan/20SF21 1/2020	1	3	4	6
57 - BetaCoV/Guangdong/20SF201/2020	5	13	18	6
63 - BetaCoV/Australia/VICO1/2020	14	8	22	7
66 - BetaCoV/USA/WA1-A12/2020	8	1	9	7
67 - BetaCoV/USA/W A 1-F6/2020	1	6	7	7
71 - BetaCoV/England/01/2020	5	2	7	7
72 - BetaCoV/England/02/2020	3	3	6	7
73 - BetaCoV/Finland/1/2020	4	2	6	7
74 - BetaCoV/USA/CA3/2020	3	1	4	7
75 - BetaCoV/USA/CA4/2020	1	2	3	7
76 - BetaCoV/USA/CA5/2020	3	6	9	7
82 - BetaCoV/Belgium/GHB-0302 1/2020	8	0	8	7

Table 18. Intra-cluster similarities (network for +3 reading frames).

Cluster	Avg. similarity	SD	Min. similarity	Max. similarity	Cluster size
0	0.277353	0.088247	0.250620	0.999866	24
1	0.999730	0.000222	0.999231	1.000000	9
2	0.998768	0.001345	0.996387	1.000000	6
3	0.999388	0.000391	0.998461	0.999933	9
4	0.999915	0.000048	0.999832	1.000000	11
5	0.896098	0.111390	0.781909	0.999899	7
6	0.999926	0.000036	0.999866	1.000000	6
7	0.997900	0.002419	0.991158	1.000000	10

Acknowledgements

We want to thank the laboratories and researchers who contributed the genomic research data used in this study and obtained via the *GISAID EpiFlu Database*™ [3] on Monday, February 10th 2020. The following tables contain information about the origination of the research data used in this study and give credit to the collecting and submitting researchers and laboratories.

[3] https://www.gisaid.org/

Table 19. Nucleotide sequences used in this study that were obtained from the GISAID EpiFlu Database™.

Collection date	Sequence id	Originating lab	Submitting lab	Authors
24/12/19	BetaCoV/Wuhan/IPBCAMS-WH-01/2019	Institute of Pathogen Biology	Institute of Pathogen Biology, Chinese Academy of Medical Sciences	Lili Ren, Jianwei Wang, Qi Jin, Zichun Xiang, Zhigiang Wu, Chao Wu, Yiwei Liu
26/12/19	BetaCov/Wuhan/WHO01/2019	General Hospital of Central Theater Command of People	BGI	Weijun Chen, Yuhai Bi, Weifeng Shi and Zhenhong Hu
30/12/19	BetaCoV/Wuhan/IV DC-HB-01/2019	National Institute for Viral Disease Control and Prevention	National Institute for Viral Disease Control and Prevention, China CDC	Wenjie TanXiang ZhaoWenling Wang Xuejun MaYongzhong JiangRoujian Lu, Ji Wang, Weimin ZhouPeihua NiuPeipei LiuFaxian ZhanWeifeng ShiBaoying HuangJun LiuLi ZhaoYao MengXiaozhou HeFei YeNa ZhuYang LiJing ChenWenbo XuGeorge F. GaoGuizhen Wu
30/12/19	BetaCoV/Wuhan/IV DC-HB-05/2019	National Institute for Viral Disease Control and Prevention	National Institute for Viral Disease Control and Prevention, China CDC	Wenjie TanXuejun MaXiang ZhaoWenling Wang Yongzhong JiangRoujian LuJi WangPeihua Niu, Weimin Zhou, Faxian ZhanWeifeng ShiBaoying HuangJun LiuLi ZhaoYao MengFei YeNa Zhu, Xiaozhou HePeipei Liu, Yang LiJing ChenWenbo XuGeorge F. GaoGuizhen Wu
30/12/19	BetaCoV/Wuhan/WIV04/2019	Wuhan Jinyintan Hospital	Wuhan Institute of Virology, Chinese Academy of Sciences	Peng Zhou, Xing-Lou Yang, Ding-Yu Zhang, Lei Zhang, Yan Zhu, Hao-Rui Si, Zhengli Shi
30/12/19	BetaCoV/Wuhan/WIV02/2019	Wuhan Jinyintan Hospital	Wuhan Institute of Virology, Chinese Academy of Sciences	Peng Zhou, Xing-Lou Yang, Ding-Yu Zhang, Lei Zhang, Yan Zhu, Hao-Rui Si, Zhengli Shi
30/12/19	BetaCoV/Wuhan/WIV05/2019	Wuhan Jinyintan Hospital	Wuhan Institute of Virology, Chinese Academy of Sciences	Peng Zhou, Xing-Lou Yang, Ding-Yu Zhang, Lei Zhang, Yan Zhu, Hao-Rui Si, Zhengli Shi
30/12/19	BetaCoV/Wuhan/WIV06/2019	Wuhan Jinyintan Hospital	Wuhan Institute of Virology, Chinese Academy of Sciences	Peng Zhou, Xing-Lou Yang, Ding-Yu Zhang, Lei Zhang, Yan Zhu, Hao-Rui Si, Zhengli Shi
30/12/19	BetaCoV/Wuhan/WIV07/2019	Wuhan Jinyintan Hospital	Wuhan Institute of Virology, Chinese Academy of Sciences	Peng Zhou, Xing-Lou Yang, Ding-Yu Zhang, Lei Zhang, Yan Zhu, Hao-Rui Si, Zhengli Shi
30/12/19	BetaCoV/Wuhan/HBCDC-HB-01/2019	Wuhan Jinyintan Hospital	Hubei Provincial Center for Disease Control and Prevention	Bin Fang, Xiang Li, Xiao Yu, Linlin Liu, Bo Yang, Faxian Zhan, Guojun Ye, Xixiang Huo, Jungiang Xu, Bo Yu, Kun Cai, Jing Li, Yongzhong Jiang.
30/12/19	BetaCoV/Wuhan/IPBCAMS-WH-04/2019	Institute of Pathogen Biology	Institute of Pathogen Biology, Chinese Academy of Medical Sciences	Lili Ren, Jianwei Wang, Qi Jin, Zichun Xiang, Zhigiang Wu, Chao Wu, Yiwei Liu
30/12/19	BetaCoV/Wuhan/IPBCAMS-WH-03/2019	Institute of Pathogen Biology	Institute of Pathogen Biology, Chinese Academy of Medical Sciences	Lili Ren, Jianwei Wang, Qi Jin, Zichun Xiang, Zhigiang Wu, Chao Wu, Yiwei Liu
30/12/19	BetaCoV/Wuhan/IPBCAMS-WH-02/2019	Institute of Pathogen Biology	Institute of Pathogen Biology, Chinese Academy of Medical Sciences	Lili Ren, Jianwei Wang, Qi Jin, Zichun Xiang, Zhigiang Wu, Chao Wu, Yiwei Liu
1/01/20	BetaCoV/Wuhan/IV DC-HB-04/2020	National Institute for Viral Disease Control and Prevention	National Institute for Viral Disease Control and Prevention, China CDC	Wenjie TanXiang ZhaoWenling WangXuejyun MaYongzhong JiangRoujian LuJi WangWeimin ZhouPeihua NiuPeipei LiuFaxian ZhanWeifeng ShiBaoying HuangJun LiuLi ZhaoYao MengXiaozhou HeFei YeNa ZhuYang LiJing ChenWenbo XuGeorge F. GaoGuizhen Wu
1/01/20	BetaCoV/Wuhan/IPBCAMS-WH-05/2020	Institute of Pathogen Biology	Institute of Pathogen Biology, Chinese Academy of Medical Sciences	Lili Ren, Jianwei Wang, Qi Jin, Zichun Xiang, Zhigiang Wu, Chao Wu, Yiwei Liu
1/01/20	BetaCov/Wuhan/WH03/2020	General Hospital of Central Theater Command of People	BGI	Weijun Chen, Yuhai Bi, Weifeng Shi and Zhenhong Hu
2/01/20	BetaCoV/China/WHU01/2020	unknown	State Key Laboratory of Virology, Wuhan University	Chen,L., Liu,W., Zhang,Q., Xu,K., Ye,G., Wu,W., Sun,Z., Liu,F., Wu,K., Mei, Y., Zhang,W., Chen, Y., Li,Y., Shi,M., Lan,K. and Liu,Y.
2/01/20	BetaCoV/China/WHU02/2020	unknown	State Key Laboratory of Virology, Wuhan University	Chen,L., Liu,W., Zhang,Q., Xu,K., Ye,G., Wu,W., Sun,Z., Liu,F., Wu,K., Mei, Y., Zhang,W., Chen, Y., Li,Y., Shi,M., Lan,K. and Liu,Y.
5/01/20	BetaCov/Wuhan/WH04/2020	General Hospital of Central Theater Command of People	BGI	Weijun Chen, Yuhai Bi, Weifeng Shi and Zhenhong Hu
8/01/20	BetaCoV/Nonthaburi/6 1/2020	Bamrasnaradura Hospital	1. Department of Medical Sciences, Ministry of Public Health, Thailand	NA
10/01/20	BetaCoV/Shenzhen/HKU-SZ-002/2020	The University of Hong Kong - Shenzhen Hospital	Li Ka Shing Faculty of Medicine, The University of Hong Kong	Chan,J.F.-W., Yuan,S., Kok,K.H., To,K.K.-W., Chu,H., Yang,J., Xing,F., Liu,J., Yip,C.C.-Y., Poon,R.W–S., Tsai,H.W., Lo,S.K.-F., Chan,K.H., Poon,V.K.-M., Chan,W.M.., Ip,J.D., Cai,J.P., Cheng,V.C.-C., Chen,H., Hui,C.K.-M. and Yuen,K.Y.
11/01/20	BetaCoV/Shenzhen/HKU-SZ-005/2020	The University of Hong Kong - Shenzhen Hospital	Li Ka Shing Faculty of Medicine, The University of Hong Kong	Chan,J.F.-W., Yuan,S., Kok,K.H., To,K.K.-W., Chu,H., Yang,J., Xing,F., Liu,J., Yip,C.C.-Y., Poon,R.W–S., Tsai,H.W., Lo,S.K.-F., Chan,K.H., Poon,V.K.-M., Chan,W.M.., Ip,J.D., Cai,J.P., Cheng,V.C.-C., Chen,H., Hui,C.K.-M. and Yuen,K.Y.
11/01/20	BetaCoV/Jiangxi/IV DC-JX-002/2020	National Institute for Viral Disease Control and Prevention	National Institute for Viral Disease Control	Wenjie Tan, Yong Shi, Wenling Wang, Peihua Niu, Roujian Lu, Jianxiong Li, Xiang Zhao, Baoying Huang, Li Zhao, Fei Ye, Wenbo Xu, George F. Gao, Guizhen Wu

Table 20. Nucleotide sequences used in this study that were obtained from the GISAID EpiFlu Database™(contd.).

Collection date	Sequence id	Originating lab	Submitting lab	Authors
13/01/20	BetaCoV/Nonthaburi/74/2020	Bamrasnaradura Hospital	1. Department of Medical Sciences, Ministry of Public Health, Thailand	NA
13/01/20	BetaCoV/Shenzhen/SZTH-00 1/2020	Shenzhen Third People	Shenzhen Key Laboratory of Pathogen and Immunity, National Clinical Research Center for Infectious	Yang Yang, Chenguang Shen, Li Xing, Zhixiang Xu, Haixia Zheng, Yingxia Liu
13/01/20	BetaCoV/Shenzhen/SZTH-002/2020	Shenzhen Key Laboratory of Pathogen and Immunity	Shenzhen Key Laboratory of Pathogen and Immunity, National Clinical Research Center for Infectious Disease,	Yang Yang, Chenguang Shen, Li Xing, Zhixiang Xu, Haixia Zheng, Yingxia Liu
14/01/20	BetaCoV/Guangdong/20SFO0 12/2020	Guangdong Provincial Center for Diseases Control and Prevention	Department of Microbiology, Guangdong Provincial Center for Diseases Control and Prevention	Min Kang, Jie Wu, Jing Lu, Tao Liu, Baisheng Li, Shujiang Mei, Feng Ruan, Lifeng Lin, Changwen Ke, Haojie Zhong, Yingtao Zhang, Lirong Zou, Xuguang Chen, Qi Zhu, Jianpeng Xiao, Jianxiang Geng, Zhe Liu, Jianxiong Hu, Weilin Zeng, Xing Li, Yuhuang Liao, Xiujuan Tang, Songjian Xiao, Ying Wang, Yingchao Song, Xue Zhuang, Liyun Liang, Guanhao He, Huihong Deng, Tie Song, Jianfeng He, Wenjun Ma
15/01/20	BetaCoV/Guangdong/20SFO0 13/2020	Guangdong Provincial Center for Diseases Control and Prevention	Department of Microbiology, Guangdong Provincial Center for Diseases Control and Prevention	Min Kang, Jie Wu, Jing Lu, Tao Liu, Baisheng Li, Shujiang Mei, Feng Ruan, Lifeng Lin, Changwen Ke, Haojie Zhong, Yingtao Zhang, Lirong Zou, Xuguang Chen, Qi Zhu, Jianpeng Xiao, Jianxiang Geng, Zhe Liu, Jianxiong Hu, Weilin Zeng, Xing Li, Yuhuang Liao, Xiujuan Tang, Songjian Xiao, Ying Wang, Yingchao Song, Xue Zhuang, Liyun Liang, Guanhao He, Huihong Deng, Tie Song, Jianfeng He, Wenjun Ma
15/01/20	BetaCoV/Guangdong/20SFO0 14/2020	Guangdong Provincial Center for Diseases Control and Prevention	Department of Microbiology, Guangdong Provincial Center for Diseases Control and Prevention	Min Kang, Jie Wu, Jing Lu, Tao Liu, Baisheng Li, Shujiang Mei, Feng Ruan, Lifeng Lin, Changwen Ke, Haojie Zhong, Yingtao Zhang, Lirong Zou, Xuguang Chen, Qi Zhu, Jianpeng Xiao, Jianxiang Geng, Zhe Liu, Jianxiong Hu, Weilin Zeng, Xing Li, Yuhuang Liao, Xiujuan Tang, Songjian Xiao, Ying Wang, Yingchao Song, Xue Zhuang, Liyun Liang, Guanhao He, Huihong Deng, Tie Song, Jianfeng He, Wenjun Ma
15/01/20	BetaCoV/Guangdong/20SF025/2020	Guangdong Provincial Center for Diseases Control and Prevention	Department of Microbiology, Guangdong Provincial Center for Diseases Control and Prevention	Min Kang, Jie Wu, Jing Lu, Tao Liu, Baisheng Li, Shujiang Mei, Feng Ruan, Lifeng Lin, Changwen Ke, Haojie Zhong, Yingtao Zhang, Lirong Zou, Xuguang Chen, Qi Zhu, Jianpeng Xiao, Jianxiang Geng, Zhe Liu, Jianxiong Hu, Weilin Zeng, Xing Li, Yuhuang Liao, Xiujuan Tang, Songjian Xiao, Ying Wang, Yingchao Song, Xue Zhuang, Liyun Liang, Guanhao He, Huihong Deng, Tie Song, Jianfeng He, Wenjun Ma
15/01/20	BetaCoV/Sichuan/ITVDC-SC-00 1/2020	National Institute for Viral Disease Control and Prevention	National Institute for Viral Disease Control	Wenjie Tan, Jianan Xu, Wenling Wang, Peihua Niu, Roujian Lu, Huiping Yang, Xiang Zhao, Baoying Huang, Li Zhao, Fei Ye, Wenbo Xu, George F. Gao, Guizhen Wu
16/01/20	BetaCoV/Zhejiang/WZ-0 1/2020	Zhejiang Provincial Center for Disease Control and Prevention	Department of Microbiology, Zhejiang Provincial Center for Disease Control and Prevention	Yin Chen, Yanjun Zhang, Haiyan Mao, Junhang Pan, Xiuyu Lou, Yiyu Lu, Juying Yan, Hanping Zhu, Jian Gao, Yan Feng, Yi Sun, Hao Yan, Zhen Li, Yisheng Sun, Liming Gong, Qiong Ge, Wen Shi, Xinying Wang, Wenwu Yao, Zhangnv Yang, Fang Xu, Chen Chen, Enfu Chen, Zhen Wang, Zhiping Chen, Jianmin Jiang, Chonggao Hu
16/01/20	BetaCoV/Shenzhen/SZTH-003/2020	Shenzhen Key Laboratory of Pathogen and Immunity	Shenzhen Key Laboratory of Pathogen and Immunity, National Clinical Research Center for Infectious Disease,	Yang Yang, Chenguang Shen, Li Xing, Zhixiang Xu, Haixia Zheng, Yingxia Liu
16/01/20	BetaCoV/Shenzhen/SZTH-004/2020	Shenzhen Key Laboratory of Pathogen and Immunity	Shenzhen Key Laboratory of Pathogen and Immunity, National Clinical Research Center for Infectious Disease,	Yang Yang, Chenguang Shen, Li Xing, Zhixiang Xu, Haixia Zheng, Yingxia Liu
17/01/20	BetaCoV/Guangdong/20SF028/2020	Guangdong Provincial Center for Diseases Control and Prevention	Department of Microbiology, Guangdong Provincial Center for Diseases Control and Prevention	Min Kang, Jie Wu, Jing Lu, Tao Liu, Baisheng Li, Shujiang Mei, Feng Ruan, Lifeng Lin, Changwen Ke, Haojie Zhong, Yingtao Zhang, Lirong Zou, Xuguang Chen, Qi Zhu, Jianpeng Xiao, Jianxiang Geng, Zhe Liu, Jianxiong Hu, Weilin Zeng, Xing Li, Yuhuang Liao, Xiujuan Tang, Songjian Xiao, Ying Wang, Yingchao Song, Xue Zhuang, Liyun Liang, Guanhao He, Huihong Deng, Tie Song, Jianfeng He, Wenjun Ma

Table 21. Nucleotide sequences used in this study that were obtained from the GISAID EpiFlu Database™(contd.).

Collection date	Sequence id	Originating lab	Submitting lab	Authors
17/01/20	BetaCoV/Zhejiang/WZ-02/2020	Zhejiang Provincial Center for Disease Control and Prevention	Department of Microbiology, Zhejiang Provincial Center for Disease Control and Prevention	Yanjun Zhang, Yin Chen, Haiyan Mao, Junhang Pan, Xiuyu Lou, Yiyu Lu, Juying Yan, Hanping Zhu, Jian Gao, Yan Feng, Yi Sun, Hao Yan, Zhen Li, Yisheng Sun, Liming Gong, Qiong Ge, Wen Shi, Xinying Wang, Wenwu Yao, Zhangnv Yang, Fang Xu, Chen Chen, Enfu Chen, Zhen Wang, Zhiping Chen, Jianmin Jiang, Chonggao Hu
17/01/20	BetaCoV/Yunnan/IVDC- Y N-003/2020	National Institute for Viral Disease Control and Prevention	National Institute for Viral Disease Control	Wenjie TanXiaoging FuXiang ZhaoWenling Wang Peihua NiuRoujian Lu,Yanhong SunBaoying HuangLi ZhaoFei YeWenbo XuGeorge F. GaoGuizhen Wu
18/01/20	BetaCoV/Guangdong/20SF040/2020	Guangdong Provincial Center for Diseases Control and Prevention	Department of Microbiology, Guangdong Provincial Center for Diseases Control and Prevention	Min Kang, Jie Wu, Jing Lu, Tao Liu, Baisheng Li, Shujiang Mei, Feng Ruan, Lifeng Lin, Changwen Ke, Haojie Zhong, Yingtao Zhang, Lirong Zou, Xuguang Chen, Qi Zhu, Jianpeng Xiao, Jianxiang Geng, Zhe Liu, Jianxiong Hu, Weilin Zeng, Xing Li, Yuhuang Liao, Xiujuan Tang, Songjian Xiao, Ying Wang, Yingchao Song, Xue Zhuang, Liyun Liang, Guanhao He, Huihong Deng, Tie Song, Jianfeng He, Wenjun Ma
18/01/20	BetaCoV/Chongqing/IVDC-CQ-00 1/2020	National Institute for Viral Disease Control and Prevention	National Institute for Viral Disease Control	Wenjie Tan, Henggin Wang, Xiang Zhao, Wenling Wang, Peihua Niu, Roujian Lu, Sheng Ye, Baoying Huang, Li Zhao, Fei Ye, Wenbo Xu, George F. Gao, Guizhen Wu
18/01/20	BetaCoV/Beijing/IV DC-BJ-005/2020	National Institute for Viral Disease Control and Prevention	National Institute for Viral Disease Control	Wenjie Tan,Quanyi Wang,Wenling Wang, Peihua Niu,Roujian Lu,Yang Pan,Xiang Zhao,Baoying Huang,Li Zhao,Fei Ye,Wenbo Xu,George F. Gao,Guizhen Wu
19/01/20	BetaCoV/USA/WA 1/2020	Providence Regional Medical Center	Division of Viral Diseases, Centers for Disease Control and Prevention	Queen,K., Tao, Y., Li,Y., Paden,C.R., Lu,X., Zhang,J., Gerber,S.I., Lindstrom,S., Tong,S.
19/01/20	BetaCoV/Hangzhou/HZCDC000 1/2020	Hangzhou Center for Disease Control and Prevention	Hangzhou Center for Disease Control and Prevention	Jun Li, Haogiu Wang, Hua Yu, Lingfeng Mao, Xinfen Yu, Zhou Sun, Qingxin Kong, Xin Qian, Shuchang Chen, Xuchu Wang
19/01/20	BetaCoV/Shandong/IVDC-SD-00 1/2020	National Institute for Viral Disease Control and Prevention	National Institute for Viral Disease Control	Wenjie Tan, Zhaoguo Wang, Xiang Zhao, Wenling Wang, Peihua Niu, Roujian Lu, Ti Liu, Baoying Huang, Li Zhao, Fei Ye, Wenbo Xu, George F. Gao, Guizhen Wu
19/01/20	BetaCoV/Jiangsu/IVDC-JS-00 1/2020	National Institute for Viral Disease Control and Prevention	National Institute for Viral Disease Control	Wenjie Tan, Shenjiao Wang, Wenling Wang, Peihua Niu, Roujian Lu, Kangchen Zhao, Xiang Zhao, Baoying Huang, Li Zhao, Fei Ye, Wenbo Xu, George F. Gao, Guizhen Wu
20/01/20	BetaCoV/Zhejiang/Hangzhou- 1/2020	Hangzhou Center for Disease and Control Microbiology Lab	Hangzhou Center for Disease and Control Microbiology Lab	Yu Hua, Wang Haogiu, Li Jun, Yu Xinfeng
21/01/20	BetaCoV/USA/IL 1/2020	IL Department of Public Health Chicago Laboratory	Pathogen Discovery, Respiratory Viruses Branch, Division of Viral Diseases, Centers for Dieases Control and	NA
21/01/20	BetaCoV/Chonggqing/Y C0 1/2020	Yongchuan District Center for Disease Control and Prevention	Chongqing Municipal Center for Disease Control and Prevention	Ye Sheng, Tang Yun, Ling Hua, Yu zhen,Chen Shuang,Tan ZhangPing, Su Kun, Li Qing, Tang Wenge, Rong Rong
22/01/20	BetaCoV/USA/CA2/2020	California Department of Public Health	Pathogen Discovery, Respiratory Viruses Branch, Division of Viral Diseases, Centers for Dieases Control and	NA
22/01/20	BetaCoV/USA/AZ1/2020	Arizona Department of Health Services	Pathogen Discovery, Respiratory Viruses Branch, Division of Viral Diseases, Centers for Disease Control and	NA
22/01/20	BetaCoV/Guangdong/20SF174/2020	Guangdong Provincial Center for Diseases Contorl and Prevention	Guangdong Provincial Center for Disease Control and Prevention	Min Kang, Jie Wu, Jing Lu, Tao Liu, Baisheng Li, Shujiang Mei, Feng Ruan, Lifeng Lin, Changwen Ke, Haojie Zhong, Yingtao Zhang, Lirong Zou, Xuguang Chen, Qi Zhu, Jianpeng Xiao, Jianxiang Geng, Zhe Liu, Jianxiong Hu, Weilin Zeng, Xing Li, Yuhuang Liao, Xiujuan Tang, Songjian Xiao, Ying Wang, Yingchao Song, Xue Zhuang, Liyun Liang, Guanhao He, Huihong Deng, Tie Song, Jianfeng He, Wenjun Ma
22/01/20	BetaCoV/Guangzhou/20SF206/2020	Guangdong Provincial Center for Diseases Contorl and Prevention	Guangdong Provincial Center for Diseases Control and Prevention	Min Kang, Jie Wu, Jing Lu, Tao Liu, Baisheng Li, Shujiang Mei, Feng Ruan, Lifeng Lin, Changwen Ke, Haojie Zhong, Yingtao Zhang, Lirong Zou, Xuguang Chen, Qi Zhu, Jianpeng Xiao, Jianxiang Geng, Zhe Liu, Jianxiong Hu, Weilin Zeng, Xing Li, Yuhuang Liao, Xiujuan Tang, Songjian Xiao, Ying Wang, Yingchao Song, Xue Zhuang, Liyun Liang, Guanhao He, Huihong Deng, Tie Song, Jianfeng He, Wenjun Ma

Table 22. Nucleotide sequences used in this study that were obtained from the GISAID EpiFlu Database™(contd.).

Collection date	Sequence id	Originating lab	Submitting lab	Authors
22/01/20	BetaCo V/Foshan/20SF207/2020	Guangdong Provincial Center for Diseases Control and Prevention	Guangdong Provincial Center for Diseases Control and Prevention	Min Kang, Jie Wu, Jing Lu, Tao Liu, Baisheng Li, Shujiang Mei, Feng Ruan, Lifeng Lin, Changwen Ke, Haojie Zhong, Yingtao Zhang, Lirong Zou, Xuguang Chen, Qi Zhu, Jianpeng Xiao, Jianxiang Geng, Zhe Liu, Jianxiong Hu, Weilin Zeng, Xing Li, Yuhuang Liao, Xiujuan Tang, Songjian Xiao, Ying Wang, Yingchao Song, Xue Zhuang, Liyun Liang, Guanhao He, Huihong Deng, Tie Song, Jianfeng He, Wenjun Ma
22/01/20	BetaCo V/Foshan/20SF2 10/2020	Guangdong Provincial Center for Diseases Control and Prevention	Guangdong Provincial Center for Diseases Control and Prevention	Min Kang, Jie Wu, Jing Lu, Tao Liu, Baisheng Li, Shujiang Mei, Feng Ruan, Lifeng Lin, Changwen Ke, Haojie Zhong, Yingtao Zhang, Lirong Zou, Xuguang Chen, Qi Zhu, Jianpeng Xiao, Jianxiang Geng, Zhe Liu, Jianxiong Hu, Weilin Zeng, Xing Li, Yuhuang Liao, Xiujuan Tang, Songjian Xiao, Ying Wang, Yingchao Song, Xue Zhuang, Liyun Liang, Guanhao He, Huihong Deng, Tie Song, Jianfeng He, Wenjun Ma
22/01/20	BetaCoV/Foshan/20SF21 1/2020	Guangdong Provincial Center for Diseases Control and Prevention	Guangdong Provincial Center for Diseases Control and Prevention	Min Kang, Jie Wu, Jing Lu, Tao Liu, Baisheng Li, Shujiang Mei, Feng Ruan, Lifeng Lin, Changwen Ke, Haojie Zhong, Yingtao Zhang, Lirong Zou, Xuguang Chen, Qi Zhu, Jianpeng Xiao, Jianxiang Geng, Zhe Liu, Jianxiong Hu, Weilin Zeng, Xing Li, Yuhuang Liao, Xiujuan Tang, Songjian Xiao, Ying Wang, Yingchao Song, Xue Zhuang, Liyun Liang, Guanhao He, Huihong Deng, Tie Song, Jianfeng He, Wenjun Ma
23/01/20	BetaCoV/Taiwan/2/2020	Centers for Disease Control	Centers for Disease Control, R.O.C.	Ji-Rong Yang, Yu-Chi Lin, Jung-Jung Mu, Ming-Tsan Liu, Shu- Ying Li
23/01/20	BetaCoV/USA/CA1/2020	California Department of Public Health	Pathogen Discovery, Respiratory Viruses Branch, Division of Viral Diseases, Centers for Dieases Control and	NA
23/01/20	BetaCoV/Guangdong/20SF201/2020	Guangdong Provincial Center for Diseases Control and Prevention	Guangdong Provincial Center for Diseases Control and Prevention	Min Kang, Jie Wu, Jing Lu, Tao Liu, Baisheng Li, Shujiang Mei, Feng Ruan, Lifeng Lin, Changwen Ke, Haojie Zhong, Yingtao Zhang, Lirong Zou, Xuguang Chen, Qi Zhu, Jianpeng Xiao, Jianxiang Geng, Zhe Liu, Jianxiong Hu, Weilin Zeng, Xing Li, Yuhuang Liao, Xiujuan Tang, Songjian Xiao, Ying Wang, Yingchao Song, Xue Zhuang, Liyun Liang, Guanhao He, Huihong Deng, Tie Song, Jianfeng He, Wenjun Ma
23/01/20	BetaCo V/France/IDF0372/2020	Department of Infectious and Tropical Diseases	National Reference Center for Viruses of Respiratory Infections, Institut Pasteur, Paris	Mélanie Albert, Marion Barbet, Sylvie Behillil, Méline Bizard, Angela Brisebarre, Flora Donati, Vincent Enouf, Maud Vanpeene, Sylvie van der Werf, Yazdan Yazdanpanah, Xavier Lescure.
23/01/20	BetaCoV/France/IDF0373/2020	Department of Infectious and Tropical Diseases	National Reference Center for Viruses of Respiratory Infections, Institut Pasteur, Paris	Mélanie Albert, Marion Barbet, Sylvie Behillil, Méline Bizard, Angela Brisebarre, Flora Donati, Vincent Enouf, Maud Vanpeene, Sylvie van der Werf, Yazdan Yazdanpanah, Xavier Lescure.
23/01/20	BetaCoV/Singapore/ 1/2020	Singapore General Hospital	National Public Health Laboratory	NA
23/01/20	BetaCoV/Chonggqing/ZX0 1/2020	Zhongxian Center for Disease Control and Prevention	Chongqing Municipal Center for Disease Control and Prevention	Ye Sheng, Tang Yun, Ling Hua, Zhang Hong, Yu zhen,Chen Shuang,Tan ZhangPing, Su Kun, Li Qin, Tang Wenge, Rong Rong
24/01/20	BetaCoV/Australia/NS WO 1/2020	Centre for Infectious Diseases and Microbiology Laboratory Services	NSW Health Pathology - Institute of Clinical Pathology and Medical Research	NA
25/01/20	BetaCoV/Australia/VICO1/2020	Monash Medical Centre	Collaboration between the University of Melbourne at The Peter Doherty Institute for Infection and Immunity, and	Caly,L., Seemann,T., Schultz,M., Druce,J. and Taiaroa,G
25/01/20	BetaCoV/Japan/AI/I-004/2020	Department of Virology III	Pathogen Genomics Center, National Institute of Infectious Diseases	Tsuyoshi Sekizuka, Shutoku Matsuyama, Naganori Nao, Kazuya Shirato, Shinji Watanabe, Makoto Takeda, Makoto Kuroda
25/01/20	BetaCoV/Korea/KCDC03/2020	Korea Centers for Disease Control	Korea Centers for Disease Control	Jeong-Min Kim, Yoon-Seok Chung, Namjoo Lee, Mi-Seon Kim, SangHee Woo, Hye-Joon Jo, Sehee Park, Heui Man Kim, Myung Guk Han
25/01/20	BetaCoV/USA/WA1-A12/2020	WA State Department of Health	Pathogen Discovery, Respiratory Viruses Branch, Division of Viral Diseases, Centers for Dieases Control and	NA
25/01/20	BetaCoV/USA/W A 1-F6/2020	WA State Department of Health	Pathogen Discovery, Respiratory Viruses Branch, Division of Viral Diseases, Centers for Dieases Control and	NA
25/01/20	BetaCoV/Singapore/2/2020	Singapore General Hospital	Programme in Emerging Infectious Diseases, Duke-NUS Medical School	Danielle E Anderson, Martin Linster, Yan Zhuang, Jayanthi Jayakumar, Kian Sing Chan, Lynette LE Oon, Jenny GH Low, Yvonne CF Su, Linfa Wang, Gavin JD Smith

Table 23. Nucleotide sequences used in this study that were obtained from the GISAID EpiFlu Database™(contd.).

Collection date	Sequence id	Originating lab	Submitting lab	Authors
28/01/20	BetaCoV/Germany/BavPat 1/2020	Charité Universitaétsmedizin Berlin	Charité Universitaétsmedizin Berlin, Institute of Virology	Victor M Corman, Julia Schneider, Talitha Veith, Barbara Miihlemann, Markus Antwerpen, Christian Drosten, Roman Wolfel
28/01/20	BetaCoV/Australia/QLD0O1/2020	Pathology Queensland	Public Health Virology Laboratory	Ben Huang, Alyssa Pyke, Amanda De Jong, Andrew Van Den Hurk, Carmel Taylor, David Warrilow, Doris Genge, Elisabeth Gamez, Glen Hewitson, Ian Maxwell Mackay, Inga Sultana, Jamie McMahon, Jean Barcelon, Judy Northill, Mitchell Finger, Natalie Simpson, Neelima Nair, Peter Burtonclay, Peter Moore, Sarah Wheatley, Sean Moody, Sonja Hall-Mendelin, Timothy Gardam, and Frederick Moore.
29/01/20	BetaCoV/England/01/2020	Respiratory Virus Unit	Respiratory Virus Unit, Microbiology Services Colindale, Public Health England	Monica Galiano, Shahjahan Miah, Richard Myers, Angie Lackenby, Omolola Akinbam1, Tiina Talts, Leena Bhaw, Kirstin Edwards, Jonathan Hubb, Joanna Ellis, Maria Zambon
29/01/20	BetaCoV/England/02/2020	Respiratory Virus Unit	Respiratory Virus Unit, Microbiology Services Colindale, Public Health England	Monica Galiano, Shahjahan Miah, Richard Myers, Angie Lackenby, Omolola Akinbam1, Tiina Talts, Leena Bhaw, Kirstin Edwards, Jonathan Hubb, Joanna Ellis, Maria Zambon.
29/01/20	BetaCoV/Finland/1/2020	Lapland Central Hospital	Department of Virology, University of Helsinki and Helsinki University Hospital, Helsinki, Finland	Teemu Smura, Suvi Kuivanen, Hannimari Kallio-Kokko, Olli Vapalahti
29/01/20	BetaCoV/USA/CA3/2020	California Department of Health	Pathogen Discovery, Respiratory Viruses Branch, Division of Viral Diseases, Centers for Disease Control and	NA
29/01/20	BetaCoV/USA/CA4/2020	California Department of Health	Pathogen Discovery, Respiratory Viruses Branch, Division of Viral Diseases, Centers for Dieases Control and	NA
29/01/20	BetaCoV/USA/CA5/2020	California Department of Health	Pathogen Discovery, Respiratory Viruses Branch, Division of Viral Diseases, Centers for Dieases Control and	NA
29/01/20	BetaCo V/France/IDF05 15/2020	Department of Infectious and Tropical Diseases	National Reference Center for Viruses of Respiratory Infections, Institut Pasteur, Paris	Mélanie Albert, Marion Barbet, Sylvie Behillil, Méline Bizard, Angela Brisebarre, Flora Donati, Vincent Enouf, Maud Vanpeene, Sylvie van der Werf, Yazdan Yazdanpanah, Xavier Lescure
29/01/20	BetaCov/France/IDF0626/2020	Sorbonne Université	National Reference Center for Viruses of Respiratory Infections, Institut Pasteur, Paris	Mélanie Albert, Marion Barbet, Sylvie Behillil, Méline Bizard, Angela Brisebarre, Flora Donati, Vincent Enouf, Maud Vanpeene, Sylvie van der Werf, Sonia Burrel, Anne-Genevieve Marcelin, Vincent Calvez, David Boutolleau, Elise Klément, Valérie Pourcher, Eric Caumes.
30/01/20	BetaCoV/Australia/QLD02/2020	Pathology Queensland	Public Health Virology Laboratory	Ben Huang, Alyssa Pyke, Amanda De Jong, Andrew Van Den Hurk, Carmel Taylor, David Warrilow, Doris Genge, Elisabeth Gamez, Glen Hewitson, Ian Maxwell Mackay, Inga Sultana, Jamie McMahon, Jean Barcelon, Judy Northill, Mitchell Finger, Natalie Simpson, Neelima Nair, Peter Burtonclay, Peter Moore, Sarah Wheatley, Sean Moody, Sonja Hall-Mendelin, Timothy Gardam, and Frederick Moore.
31/01/20	BetaCoV/Taiwan/NTU01/2020	Department of Laboratory Medicine	Microbial Genomics Core Lab, National Taiwan University Centers of Genomic and Precision Medicine	Shiou-Hwei Yeh, You-Yu Lin, Ya-Yun Lai, Chiao-Ling Li, Shan-Chwen Chang, Pei-Jer Chen, Sui- Yuan Chang
1/02/20	BetaCoV/Singapore/3/2020	National Centre for Infectious Diseases	Programme in Emerging Infectious Diseases, Duke-NUS Medical School	Danielle E Anderson, Martin Linster, Yan Zhuang, Jayanthi Jayakumar, David CB Lye, Yee Sin Leo, Barnaby E Young, Yvonne CF Su, Linfa Wang, Gavin JD Smith
3/02/20	BetaCoV/Belgium/GHB-0302 1/2020	KU Leuven	KU Leuven, Clinical and Epidemiological Virology	Bert Vanmechelen, Elke Wollants, Annabel Rector, Els Keyaerts, Lies Laenen, Marc Van Ranst, and Piet Maes