Traces of trade in the Tarim Basin: a case for applying network models to the study of ancient trade

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Abstract

This article will discuss the possibilities and limitations of network models and analysis in tracing ancient trade routes. In addition to a general discussion of network models, the article will present a short case study, analysing two sources for ancient Eurasian trade, namely the *Hou Hanshu* and the Kharosthi documents from Kroraina. The case will look at network models generated from these two sources, before ending on a comparison between the two models. It will be argued that network models and methodology are an important tool for improving our understanding of ancient trade.

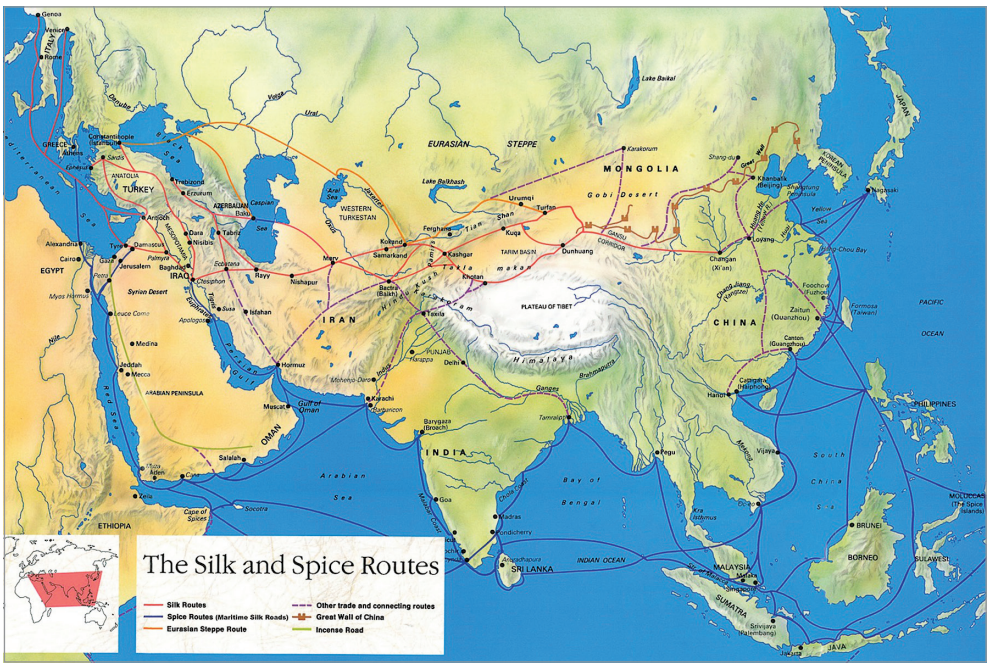

Fig. 1: Silk Routes map for Unesco's Silk Road project. Source: https://en.unesco.org/silkroad/sites/silkroad/files/SilkRoadMapOKS_big.jpg.

Introduction

Representations of historic trade upon maps are ubiquitous, and yet the act of tracing these routes is fraught with difficulty. Take, for example, the Silk Road,[1] which will serve as the case study for this

1. The term, coined by Ferdinand Freiherr von Richthofen in 1877, refers to an imagined system of trade routes stretching from China towards the West from as early as the Han dynasty. Alternative versions such as Silk Roads or Silk Routes are also commonly used. This article will use the term Silk Routes.

article. Practically every representation of the Silk Road upon a map takes the form of a network of sites represented by dots, connected by lines representing routes. Yet when looking at the sources behind these neatly drawn dots and their connecting lines the picture blurs. There are traces of items moving across Eurasia certainly, from pieces of silk with Chinese characters in the Palmyrene tomb towers[2] to ornamental corals from the Niya site[3] and Sogdian letters discovered in a Chinese watch-tower near Dunhuang.[4] These items were undoubtedly carried to their find spot by human interaction, and are sure proof that people interacted and exchanged goods, for one purpose or another, across Eurasia in Antiquity. And yet despite this visibility in the archaeological record, any attempt at tracing historic trade events, links and routes, in short, all the human activities that moved our many artefacts, is fraught with difficulty. Few of the surviving literary sources saw it a fit subject for discussion, few epitaphs were raised over traders and precious little written material was produced by their activities. Added to this the ever-present problem in the studies of the ancient world of a highly fragmented and disconnected corpus of sources, and the problems would seem all but insurmountable. But this is precisely the reason why a clearly formulated and transparent theoretical framework and a variety of methodological approaches are essential when seeking to study ancient trade.

This is not a novel revelation and scholars of ancient trade have employed and engaged with a wide range of methods and models since the very beginning—at times explicitly, though often implicitly. Fierce debates have been waged over how the phenomenon of ancient trade should be approached and conceived in almost all of the historic disciplines, from the primitivist-modernist debate in history[5] to the age-old question of historical specificity in economics.[6] And further to these debates, the question of what types of methods and models could and should be employed have been the topic of much discussion. A host of different theoretical approaches and methods have been developed and applied to a range of different areas and periods, from the well-established idea of a central place to newer methods such as cost-path analysis. And new ideas and approaches are constantly being both developed and borrowed across disciplinary boundaries.

Yet in the case of Silk Road studies, that is the studies of trade across Eurasia in the premodern period, the pace of theoretical innovation and experimentation has been remarkably slow. That is not to say that the field is without its debates, far from it. But the controversies of Silk Road studies have for the most part revolved around questions about the nature of the Silk Road itself. Who provided the impetus for the trade? To what extent and from when did Silk Road trade occur? And so on. Only in recent decades have scholars really started wrestling with the Silk Road in its own right, recognizing and discussing the implication of the Silk Road as a model, that is, as a theoretical construct. This is perplexing, as surely the Silk Road is one of the most evocative and well-known models of trade in the ancient world.

In the past two decades, David Christian and Nicola di Cosmo have raised and discussed what they found to be marked limitations of the Silk Road concept as an analytic framework and model, at least as traditionally employed.[7] Neither of these scholars makes an argument for discarding the Silk Road as such, but rather seeks to expand and reshape the traditional model. Armin Selbitschka, in his recent contribution to the *Oxford Research Encyclopedia of Asian History*, goes much further in suggesting that the concept of the Silk Road is not only limited but indeed limiting as well. He suggests that:

2. Thomas 2017, 60-61.
3. 日中共同ニヤ遺跡学術調査隊 (the Sino-Japanese Joint Research of the Niya Site) 1999, 2:96.
4. Grenet et al. 1998.
5. Seland 2017.
6. Hodgson 2002.
7. Christian 2000; Di Cosmo 2014.

> Catchphrases such as 'silk', 'road' and 'trade' are, by their very nature, exclusive in the sense that they promote oversimplifying arguments, which redact any kind of interaction between two or more discrete social entities to the exchange of Chinese silk through mercantile activities that were organized on well-established infrastructure.[8]

Rather than these, as he terms them, 'catchphrases' Selbitschka argues that a concept of movement should be the central analytical tool in Silk Road studies. By thus changing the focus of research, Selbitschka appears to seek a greater focus upon other forms of exchange and interaction across the Silk Routes, such as the movement of people or religion, as well as a deeper discussion about the intention behind this interaction.[9] I believe, however, his proposed focus on movement has another important side that Selbitschka himself does not discuss, namely that seeing movement as the central question of analysis should also force researchers to question how this movement happened, by which routes and by which means—questions that have often been neglected, or at best skimmed over, by much of the literature on the Silk Routes.

Taking this as its cue, this article proposes discussing the possibilities and problems of network models and network analysis in tracing the routes of ancient trade, with the Silk Road as a case study. It will commence with a more general discussion on the possibilities and limitations of network analysis in tracing historic trade routes before moving on to the case study. The case study will seek to accomplish two things. Firstly, it will analyse two of the primary sources for exchange across central Asia in the period from the 2nd to the 4th century, namely the *Hou Hanshu* and the Kharosthi material from Kroraina, using network methods. This will be done in an effort to exemplify some of the advantages and disadvantages discussed initially. Secondly, it will look at how comparing networks generated from these two sources can allow new insights into the relationship between the information they contain and how the use of network models can facilitate this comparison. Due to the nature of the Krorainan material, as well as the constraints of the paper, the case will focus on tracing movement through the southern Tarim Basin. First, however, a short introduction to the basics of network theory will be given.

Network models and ancient trade

Network analysis is a method rooted in mathematical graph theory, from which its techniques for constructing models and examining them are derived. Drawing on several breakthroughs in graph theory from the 1950s, the method was first adopted into anthropology and sociology and it was not until fairly recently that network theory was also adopted by historians and archaeologists.[10] Within the studies of Antiquity, network theory has been adopted and applied to a wide range of settings and issues, drawing inspiration from a variety of earlier works in sociology and anthropology.[11] The applications have ranged from as different topics as the studies of epistolary networks[12] to the structures underpinning the Roman brick-making industry.[13] And though the majority of studies, at least those by historians, have focused on social networks, a steadily growing body of research has applied network theory and network methods to cases of ancient trade, transportation and movement patterns as well. Of particular note are the joint work of Rivers, Knappett and Evans on modelling Bronze Age

8. Selbitschka 2018, 2.
9. Selbitschka 2018, 2-3.
10. For a very informative overview of the development of network theory see Ruffini 2008, 8-14. See also Newman et al. 2006, chap. 1.
11. Brughmans 2010.
12. Alexander and Danowski 1990.
13. Graham 2002.

networks in the Aegean[14] and Irad Malkin's work on networks and the growth of the Greek world,[15] though many others could be mentioned. Particularly inspiring to this paper has been the work of Leif Isaksen on Roman itineraries, where he utilizes network analysis to explore sections of these itineraries and also attempts comparisons between them.[16]

Network methodology has several characteristics that make it a useful tool for studying ancient trade. The primary advantage and purpose of any scientific model is to replicate a given object of study in such a way as to make it more accessible to the researcher. This can, of course, take a multitude of forms, from scale models of a Roman villa to theoretical models such as central place theory, which seeks to describe a certain phenomenon. A network model is however primarily what Christian Meyer has termed an 'analytical model', that is, a model whose primary purpose is to allow for a certain type of logic or analysis to be applied.[17] In a sense, the 'analytical model' forces the research to focus on just a few aspects of the subject matter, which are the aspects the model seeks to reproduce. And in the case of network models these are the relationships and the interaction between different entities described within a given source material.[18] As such, network models and methods would seem to be an ideal tool with which to approach ancient trade, where one of the primary research interests is precisely the way various actors, settlements, regions, states and other such entities interacted economically.

More than just focusing the research, network methodology, with its many analytical tools developed from graph theory, allows the researcher to explore the models with a range of different measures and even to conduct experiments. Centrality measures, which will be employed in the case study to follow, can for example be used to identify important hubs, connectors and choke points in the network. Clustering, on the other hand, can be used to detect groupings of entities that appear to be particularly close or well connected. In the breadth of possible analytical tools that can be applied from what Isaksen terms the 'umbrella' of network theory[19] also lies a lot of flexibility, which makes it easy to tailor the methodology to the study at hand. Furthermore, as an analytic model mainly concerned with the relationship between entities, what these entities reflect, be it people or places, and the nature of their connections, whether it is letters or routes of movement, is of lesser importance. This allows for a very broad range of applications and approaches, from using networks mainly as a conceptual framework as done by Malkin to the experimental modelling undertaken by Rivers, Knappet and Evans.

On a more cautious note, however, it should be clear that while network methods and modelling hold advantages, they also have drawbacks and should be applied with these in mind. Most prominently perhaps one must recognize that what is being modelled is not the real world as such, but rather the description of the world represented by the available sources. This is important, as many of the weaknesses of a source or the methods used in constructing the graph can easily disappear behind the glamour of the model and its results. Doubly so when applying the many analytical tools of network theory, which, as Max Black so eloquently put it, 'entails a serious risk of confusing accuracy of the mathematics with strength of empirical verification in the original field'.[20] This means that in applying network methodology, while it can allow sources to be studied in new and interesting ways, one must still wrestle with all the usual problems of source reliability and representativity. Furthermore, given that the analytical model's primary purpose is to focus the research upon certain aspects of a

14. Rivers et al. 2013.
15. Malkin 2011.
16. Isaksen 2008.
17. Meyer 2007, 238-39.
18. Brughmans 2010, 277.
19. Isaksen 2008, 7.
20. Black 1962, 225.

phenomenon, much is by necessity lost in the process of modelling and simplification. This naturally includes many of the details of the source, such as the prose or context of a written text, which in most cases will be difficult to include in the model. But also, in the process of model making, choices about generalizations and selection must be made that will inevitably impact on what the model represents and thus what insights can possibly be gleaned from it. Both these advantages and drawbacks should be kept in mind in the following sections, as the article will attempt to highlight some of these possibilities and problems in the following case study.

The method of network analysis

This article will merely scratch the surface of the many possible network approaches, and as such, just a few, key terms will be introduced.[21] In order to construct a network model a data set must first be prepared from the sources. This data set must contain a list of nodes, in this case the place names mentioned in the historical sources, and must denote when 'edges', the network term for connections or lines, are present. The data set can take a variety of forms, depending on the nature of the source material, but in this article an adjacency matrix for a one-mode network was constructed. The criteria for what constitutes an edge, and thus a connection, must be chosen in accordance with the nature of the inquiry. In this case, this was done by creating an undirected edge whenever two place names appeared together in the same document/section of the sources. A clear weakness of this approach is that even places not directly mentioned in the text as being connected will be connected in the network graph, as long as they appear together in the same document. This seems justifiable, however, under the assumption that two places appearing in the same document, even though they might not in reality have had a direct connection, should be understood as being indirectly connected via other sites. The data set, once complete, was then run through the Visone software, which generated the models to be discussed shortly.

1	Locations	Alma Bhumi	Ayamatu Vasa	Bhagasa	Bhoti-nagara	Bumni	Cadota	Calmadana	Camu Prete	China	Duki mountains	Khamni	Khema	Khotan
2	Alma Bhumi	0	0	0	0	0	1	0	0	0	0	0	0	0
3	Ayamatu Vasa	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Bhagasa	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Bhoti-nagara	0	0	0	0	0	0	0	0	0	0	0	0	0
6	Bumni	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Cadota	1	0	0	0	0	0	4	0	0	0	0	2	8
8	Calmadana	0	0	0	0	0	4	0	0	2	0	1	0	3
9	Camu Prete	0	0	0	0	0	0	0	0	0	0	0	0	0
10	China	0	0	0	0	0	0	2	0	0	0	0	0	1
11	Duki mountains	0	0	0	0	0	0	0	0	0	0	0	0	0
12	Khamni	0	0	0	0	0	0	1	0	0	0	0	0	0
13	Khema	0	0	0	0	0	2	0	0	0	0	0	0	4
14	Khotan	0	0	0	0	0	8	3	0	1	0	0	4	0
15	Kogitasasa	0	0	0	0	0	0	0	0	0	0	0	0	0
16	Kroraina	0	0	0	0	0	3	2	0	0	0	0	1	2
17	Kuci	0	0	0	0	0	1	0	0	0	0	0	0	0
18	Lominana	0	0	0	0	0	0	1	0	0	0	0	0	0
19	Masina	0	0	0	0	0	0	0	0	0	0	0	0	0
20	Navote	0	0	0	0	0	0	0	0	0	0	0	0	0
21	Nina	0	0	0	0	0	2	2	0	1	0	0	0	3
22	Opimta	0	0	0	0	0	0	1	0	1	0	0	0	1
23	Parcona Bridge	0	0	0	0	0	0	1	0	0	0	0	0	0
24	Parvata	0	0	0	0	0	4	0	0	0	0	0	0	4
25	Pisali	0	0	0	0	0	0	1	0	0	0	0	0	0
26	Protsa kresa	0	0	0	0	0	0	0	0	0	0	0	0	0
27	Pumni	0	0	0	0	0	0	0	0	0	0	0	0	0
28	Pusgari	0	0	0	0	0	0	0	0	0	0	0	0	0
29	Remena	0	0	0	0	0	1	0	0	0	0	0	1	1
30	Rocakhora	0	0	0	0	0	0	0	0	0	0	0	0	0
31	Saca	0	0	0	0	0	7	1	0	0	0	0	1	6

Fig. 2: Example of the adjacency matrix for source two. The numbers denote the number of times two sites co-appear.

21. Readers interested in a more thorough discussion and more examples of how network analysis can be utilized should see Brughmans 2010; Rivers et al. 2013; Ruffini 2008.

Once generated network analysis software also allows for a wide variety of measures and analytic tools with which the structures of the network can be studied further. The models generated from each source in this article were analysed using two centrality measures, namely *degree centrality* and *betweenness centrality*. Degree centrality is the simplest of these, being just the number of edges a node has. A high degree centrality in our context indicates that a node is mentioned frequently in the sources, suggesting it to be somehow prominent. Betweenness centrality is a little more complex. As defined by Isaksen, betweenness centrality is 'the probability that a node will be passed by traffic travelling along the shortest route between two other nodes on the network'.[22] This means that any node with a high betweenness centrality score are natural bottlenecks or hubs in the network structure connecting different sections of the network. An easy example of this would be the central node of a star-shaped network, which would naturally have a very high betweenness centrality.

The Silk Routes case

With these basics in mind, we now turn to the case study proper and our two sources, namely the Chinese chronicle known as the *Hou Hanshu*[23] (後漢書), the Book of the Later Han, and the Kharosthi documents from Kroraina. Both sources contain descriptions of *trade events* in or through central Asia in the first centuries CE, though the *Hou Hanshu* primarily deals with the 1st and 2nd centuries whereas the Krorainan documents date mainly to the 3rd and the 4th.[24] These are also very different sources, one a work of Chinese dynastic history while the other is the product primarily of a local bureaucracy. Where the *Hou Hanshu* tends to deal with politics on an imperial scale the Kharosthi documents are primarily concerned with local problems of taxation or the enforcement of law, and as such it is the Chinese sources that have primarily been used by historians discussing the Silk Routes.

In some recent accounts, such as that of Xinru Liu's *The Silk Road* (2010) or Raoul McLaughlin's *The Roman Empire and the Silk Routes* (2016), the central Asian sources are included, though in both cases as supplementary information to a greater Sino-centric narrative of a flourishing Silk Road system.[25] On the other hand, in other recent publications such as Valerie Hansen's *The Silk Road* (2012) or in Craig Benjamin's *Empires of Ancient Eurasia* (2018) these same sources have been used to argue that what the Chinese accounts related were the heydays of the Silk Route trade. These heydays were then followed by a slump in trade activity following the fall of the Han and Kushan empires around the beginning of the 3rd century. In particular, Valerie Hansen, whose discussion of the Krorainan material is the most thorough, emphasizes how these sources clearly show that overland trade in the 3rd and 4th centuries was minimal[26] and how the local economy had reverted back towards a basic sustenance economy.[27] Thus there seems to be no clear consensus amongst historians as to how these two sources relate to each other, something the following study will attempt to discuss.

22. Isaksen 2008, 7.

23. This work, the standard history of the later Han dynasty, covers the period from Wang Mang's interregnum (9-23 AD) to the fall of the Han dynasty in 221 AD. It was compiled in the 5th century at the court of the Liu Song dynasty by Fan Ye, based mainly on earlier works. See Hill 2015.

24. The documents date from about the middle of the 3rd to the middle of the 4th century CE, though the precise dating is debated.

25. Liu 2010, 59; McLaughlin 2016, 97-99.

26. Hansen 2012, 50.

27. Hansen 2012, 48-49.

The Hou Hanshu—envoys and luxuries

It was around the turn of the 2nd century CE that the *Hou Hanshu* describes several envoys arriving from a region it calls Tianzhu (天竺) carrying tribute and offerings to the Han emperor He.[28] This was after, the same chronicle tells us, the Chinese general Ban Chao had re-established Han hegemony over the Tarim Basin, a vast drainage basin that makes up the majority of modern Xinjiang, and thus secured communications westwards. Tianzhu, meaning India but here likely referring to the north-western part of the subcontinent,[29] is said to have produced wondrous resources, from elephants to turtle shells. From it is also said to have come many precious things, such as fine cotton cloth, fine woollen carpets, sugar, pepper, ginger and black salt, all substances that may well have been part of the tribute.[30] Unfortunately the Western Regions, being the kingdoms of the Tarim Basin, rebelled following Emperor He's death in 105 CE, and the relations between Tianzhu and the Han were again severed.[31]

Tributary missions of this sort make up the typical *trade* event from the *Hou Hanshu*. Other similar events appears throughout Chapter 88, the 'Treatise on the Western Regions', including the famous Andun mission said to have come from the King of Da Qin (the Roman Empire).[32] And it is trade events like this, recorded in the *Hou Hanshu* as well as the earlier *Shiji* and *Hanshu*, that have formed the basis of much of what has been written on the early Silk Road. In particular, a passage in Chapter 88, describing two routes westwards, has often been used as the basis for drawing maps, and thus models, of the Silk Routes. And yet, as the network model will show, these were far from the only forms of interaction mentioned in the *Hou Hanshu*.

Before constructing the network model from the *Hou Hanshu*, however, it was necessary, as discussed above, to construct a data set. Firstly, the analysis was delimited to only include Chapter 88, the part of the *Hou Hanshu* directly concerned with the Tarim Basin region and overlapping with the second source. Secondly, the chapter was split into sections following John Hill's separation of the text in his translation, where each *guo* (國) or country is given its own entry.[33] From Hill's 29 sections 68 individual sites were identified, and based on these nodes' co-appearance in a section an edge was drawn. The graph generated from this process is very densely connected and appears as something of a hairball (Fig. 3).

It is important to note that some of the issues of network modelling become apparent here. By following the procedure above, choices are made that condition how the network will end up being structured, and anomalies can easily appear. For example, the main reason for the network model appearing so tightly clustered is the inclusion of two sites, Liuzhong and Louyang.[34] Both sites have very prominent degree centrality scores, with Louyang having the highest and Liuzhong ranking as number five, which in our context means that they both feature very prominently in the text. This is entirely unsurprising, as Liuzhong was the seat of the highest-ranking Chinese general in the Western Regions and Louyang was the capital of the Later, also called Eastern, Han Dynasty, and both sites are included in nearly every section of Chapter 88. This is, however, not because they play an active part in the narrative as such or interact frequently with other sites, but because nearly every section starts with noting the distance from Liuzhong and Louyang to the country in question. As this hardly

28. Fan Ye, HHS, 88 (31).
29. Hill 2015, 356-57.
30. Fan Ye, HHS, 88 (31).
31. Fan Ye, HHS, 88 (7, 31).
32. Fan Ye, HHS, 88 (27).
33. Hill 2015, xvii.
34. All the identifications of places from the *Hou Hanshu* in this article are based upon the commentary of John Hill. See Hill 2015.

constitutes interaction, and in order to avoid anomalous centrality measures, these two sites were therefore deleted from the model.

The resulting network model has several noteworthy features (Fig. 4). The first, and perhaps the most important, is the level of interconnectedness between the nodes. In stark contrast to our opening Silk Route map, which, for example, for the Tarim Basin showed two road-like lines circling the Taklamakan Desert, this model shows a highly interconnected Tarim region. The connections are not constrained here to an east-west axis but rather connections are shown across the desert on the north-south axis, disregarding the commonly envisioned lines of movement through the region. The network model as a whole does not however disregard geography entirely. Not only do geographically close sites, such as Gumo (Aksu), Qiuci (Kuqa) and Yanqi (Karashar), tend to cluster but the nodes also group into three clusters, that is, groups of highly interconnected nodes, along geographic lines. The very tightly connected cluster on the right-hand side of the network encompasses sites in the Tarim Basin and its environs, as well as the nomadic people to its north such as the Wusun and Xiongnu. The cluster in the top left contains sites located in northern India, Afghanistan and eastern Iran, such as Daxia (Bactria) and Tianzhu (North India) itself. Finally, the cluster in the bottom left mainly contains sites in the far west, centred around Da Qin (the Roman Empire) and Haixi (Egypt). These three clusters are connected by just a few nodes, which, as one could guess from their positions as connectors or bottlenecks, have amongst the highest betweenness centrality scores (Fig. 5). Strikingly, the three highest scores are the Da Yuezhi (the Kushan), Anxi (Parthia) and Kangju (Talas and Sogdiana), all three realms which in much of the Silk Route literature are regularly described as the primary intermediaries or 'middlemen' between east and west.[35] The network model generated from the *Hou Hanshu* would seem to support this assertion, at least in the sense that to cross between the clusters in the network, passing either of these realms would often be the quickest way, though naturally one could equally assert that the central position of these realms perhaps challenges the traditional narrative of the Silk Routes primarily being a connection between China and Rome.

The Kharosthi documents—animals, carpets and slaves

Moving on to the second source under consideration, the Kharosthi documents from the kingdom of Kroraina are very different from the *Hou Hanshu*, both in content and context. Consisting of more than 800 documents discovered at several archaeological sites across the southern Tarim Basin, most of them by Sir Aurel Stein's three expeditions to the region, the Kharosthi documents were overwhelmingly the product of the royal administration of the kingdom of Kroraina. This kingdom occupied much of the south-eastern part of the Tarim Basin and according to the *Weilüe* it lay on the southern route around the dreaded Taklamakan Desert.[36] Being the product of a local administration, the Kharosthi documents are overwhelmingly concerned with local matters, such as taxation or legal disputes, though several contracts recording small-scale exchange were also discovered.

An example of one of the more remarkable cases of such exchange appears in document n.324, penned in the last decade of the 3rd century. The contract describes how a fearsome people known as the Supi attacked the oasis town of Calmadana, modern Qiemo. There they seized a man called Saṃrpina, slave of the *vasu* Yonu, and later proceeded to give their captive as a gift to Ṣ́gaṣi, a Chinese man. It is not known how the *vasu* Yonu learned of this, but the document explains how Ṣ́gaṣi paid the *vasu* a recompense of two golden stater and two drachma, thereby settling the matter. He was then given permission to sell the slave Saṃrpina to a third man, Katge. At this point the document breaks

35. For some examples see Benjamin 2018, Chap. 6 and 7; McLaughlin 2016, 86.
36. Yu Huan, Weilüe (Section 5).

off, as the covering tablet, which would have contained the remaining part of the text, was not found.[37] Judging from other Krorainan contracts, however, it would likely have given witnesses and the magistrates who oversaw the exchange, as well as stipulating a punishment for renegading on the agreement.

Though document n.324 includes exchange between a Chinese man and people from Kroraina, and appears to mention monetary units of gold,[38] it is one of the few examples of exchange with people from beyond the kingdom in the collection. Rather the vast majority of the contracts deal with the exchange of animals, particularly camels and sheep, and agricultural products, such as grain and wine, between local people. For this reason, the Krorainan material has rather unfortunately often been ignored in favour of the Chinese sources. Yet when laid out and explored as a network model the Krorainan sources appear to describe far more than merely a local community.

The Krorainan data set was constructed much like that of the *Hou Hanshu*. From the 763 documents discovered by Stein and included in the transcription of Boyer, Rapson and Senart,[39] 48 unique locations were identified. This excludes the locations named either *kilme* or *avana*, as these represented smaller administrative units within the oases of the kingdom. An edge was then constructed whenever two locations appeared together in one document. This method left 20 nodes unconnected to any other node in the network, and these were therefore deleted, leaving one large network of 24 nodes and two smaller networks of only two nodes each.

The result is a network model composed of a highly interconnected central cluster, surrounded by several less well-connected nodes (Fig. 6). As shown very clearly by our two centrality measures, degree and betweenness centrality, the nodes of the central cluster are also the most important hubs and thoroughfares of the network. This makes quite a lot of sense, as amongst the central cluster we find both the four major oases of the kingdom of Kroraina, namely Cadota, Saca, Calmadana and Kroraina itself, and the kingdom's two major neighbours, namely Khotan and China. The network model constructed from the Kharosthi documents would then seem to reflect a local interaction network centred upon a few oasis hubs, each with their surrounding hinterland of smaller sites. Considering the geography of the region, as well as what is known of the administrative system of Kroraina, this too makes a lot of sense. But while predominantly local, the network also has a surprisingly long geographic reach. Not only do Kroraina's two closest neighbours, Khotan and China, figure very prominently in the network model, but the northern Tarim oasis of Kuci (Kuqa/Qiuci) also appears. Far more surprising, however, is the appearance of a *suliġa*, a Sogdian, in document n.661.[40] This document is suspected, on contextual and orthographic grounds, to have originally been written in Khotan, which is also the only location mentioned within it. But finds of Sogdian documents at both the Niya site (Cadota) and the Lop sites (Kroraina) confirm that Sogdians were also active in the kingdom of Kroraina.[41] Thus, far from revealing a purely local network, the Krorainan sources in fact describe connections over vast distances, from the north-western edge of China to the north-eastern part of the Iranian world.

A case for comparing networks

So far this article has discussed the network models generated from the *Hou Hanshu* and the Kharosthi documents from Kroraina separately and indeed the models of interaction produced from these two sources are very different. This is because the sources themselves are very different, not only

37. The contract in question is Kharosthi document n.324, translated by T. Burrow in Burrow 1940, 60-61.

38. It is unclear whether the Kharosthi documents actually refer to minted coins or merely use the words 'stater' and 'drachma' as units of measure. See Wang 2004, 66-67.

39. Rapson et al. 1929.

40. Burrow 1940, 137.

41. Sims-Williams and Bi 2018; Stein 1921, 281-83; 1928, 1031.

when it comes to their authors and their perspectives but also in regard to the reasons behind their existence. On the one hand is the *Hou Hanshu*, a history mainly concerned with the actions of kings and emperors, and on the other the Kharosthi material, produced by a royal bureaucracy for the purposes of communication, taxation, legalization and so forth. This seemingly vast difference of scale is perhaps why they have been so rarely brought together and their content compared in scholarly debates on the Silk Routes. And yet here, in the possibilities for comparisons, I think lies one of the greatest strengths of the network model. By looking beyond the language and prose of the texts themselves and focusing only on the relationships and structures described therein, network models and methods make it possible to compare these sources in new ways.

For while clearly very different sources, concerned for the most part with very different human activates, there are some interesting similarities in the network structures they generate. Firstly, it is noteworthy that out of the seven sites with the highest betweenness centrality in the Krorainan network, namely Cadota, Calmadana, China, Khotan, Kroraina, Pisali and Saca, five reappear in the network from the *Hou Hanshu* (Fig. 7). These are Jingjue (Cadota), Qiemo (Calmadana), Dunhuang (likely what is meant by China), Yutian (Khotan) and Shanshan (Kroraina). And not only do they reappear but they are all connected to each other as they appear together in several sections of the *Hou Hanshu*. The more peripheral sites of Khema, Kuci and Suliga also reappear as Jumi, Qiuci and Kangju, respectively. Furthermore, the sites that belong to the kingdom of Kroraina, namely Jingjue, Qiemo and Shanshan, cluster very closely, which reflects the fact that they are regularly mentioned together in the *Hou Hanshu*. Thus, the *Hou Hanshu* model appears to mirror some of the characteristics of the Krorainan network model.

A second interesting point is that, although only Dunhuang ranks particularly high in betweenness centrality amongst the eight reappearing sites, both Shanshan (Kroraina) and Yutian (Khotan) have very high degree centrality scores, being number five and six, respectively (Fig. 8). In our context this means that these two sites, as well as Dunhuang, which ranks as number two in degree centrality, appear very frequently in multiple sections of the *Hou Hanshu*'s Chapter 88. If, as an experiment, we were to remove the nodes to the west of the Tarim Basin and conduct the analysis again, this pattern would become even clearer, with all three sites scoring high in both degree and betweenness centrality. Thus, comparing the networks in this way seems to show that, very broadly speaking, there are strong similarities in which sites appear as important nodes. This in turn would suggest that both sources appear to reflect the same reality, where certain oasis sites such as Kroraina/Shanshan and Khotan/Yutian were important hubs of movement and interaction in the southern Tarim Basin.

Conclusion

On that note it would seem prudent to ask: 'Where does one go from here?' What could be the reasons for these apparent similarities? Could it perhaps be that the Krorainan kingdom inherited a network of roads and contacts from the earlier period of Chinese domination. Or do perhaps the Chinese sources reflect primarily local structures? Or indeed, are both sources producing models mainly constrained by geographic considerations? None of these questions falls within the purview of this paper, as this is where the usefulness of these models ends and traditional qualitative analysis takes over. It does however serve to underline a last, important point concerning network models, namely that while rich in analytic potential they do not usually furnish much in the way of explanations. Analytical models are primarily concerned with modelling and exploring on the level of the particular and as such cannot and should not be taken as representing the general, be it the Silk Routes or any other phenomenon of ancient trade.

This observation, as long as it is recognized, is however not a problem as such, since the whole point of an analytical model is to provide a specific focus to an analysis. And as this article has en-

deavoured to show, network models and methods are in many ways ideally suited to doing this, at least as far as the study of ancient trade is concerned. By applying network methods and constructing network models from written sources one can delve below the prose and explore the text at a structural level. This is not without its drawbacks, and, as seen above, the method chosen for producing the model will have clear effects upon the outcome. But as long as these drawbacks are kept in mind, network models are rich in descriptive potential, allowing the text to be seen in a new light. Not only do the results gleaned from the model serve to open up new considerations and avenues of research, but by turning texts into networks it also becomes easier to compare them.

Finally, by applying the methods of network analysis in the construction of models, one is, at least ideally, consciously engaging with the procedures and choices through which said models are constructed. This is essential for two reasons: firstly, such a consciousness of method should lead to a greater transparency in how models within the field are constructed, be they represented as maps or as networks of connections; and secondly, it should lead to a greater consciousness of the relationship between the particular and the general, and thus between any given trade event and the models we construct to place these events within a greater pattern. This last point is certainly an insight that is essential to the further development of the studies of ancient Eurasian trade, where a much clearer recognition of the Silk Routes as a theoretical model is necessary.

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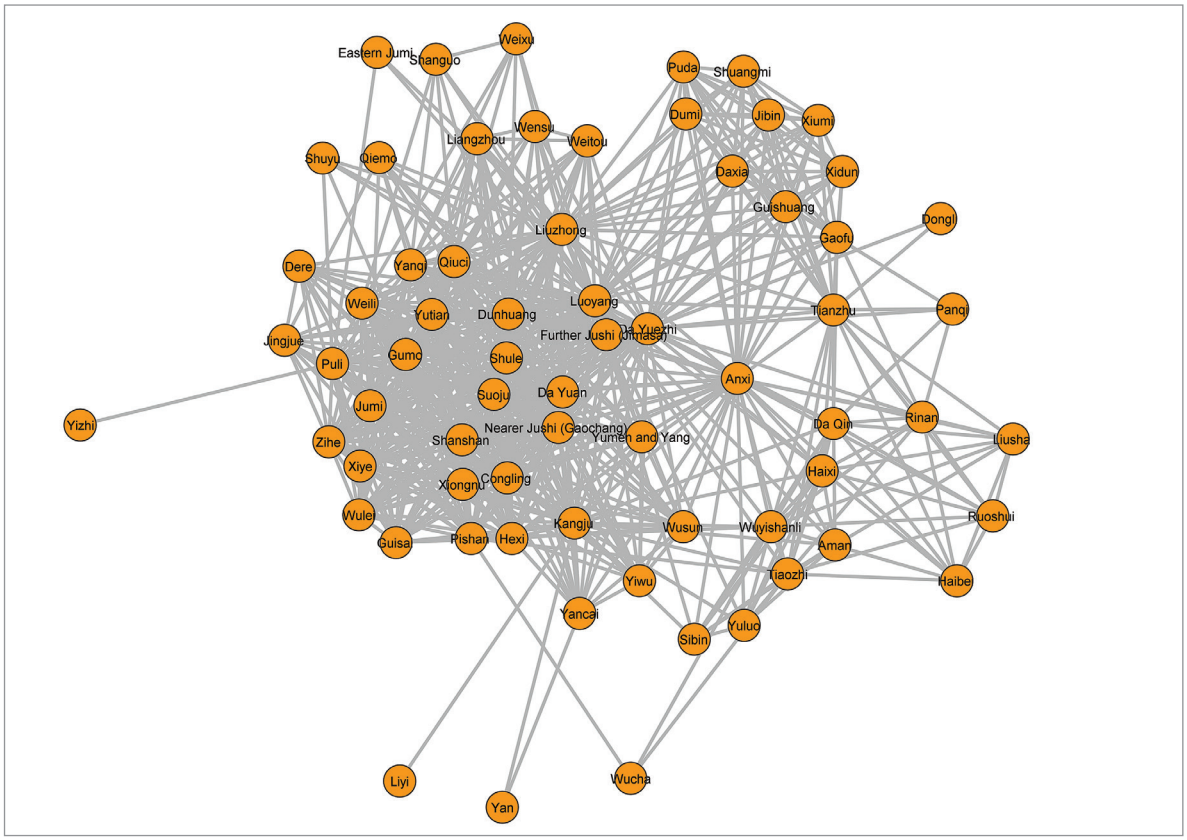

Fig. 3: The complete *Hou Hanshu* network model.

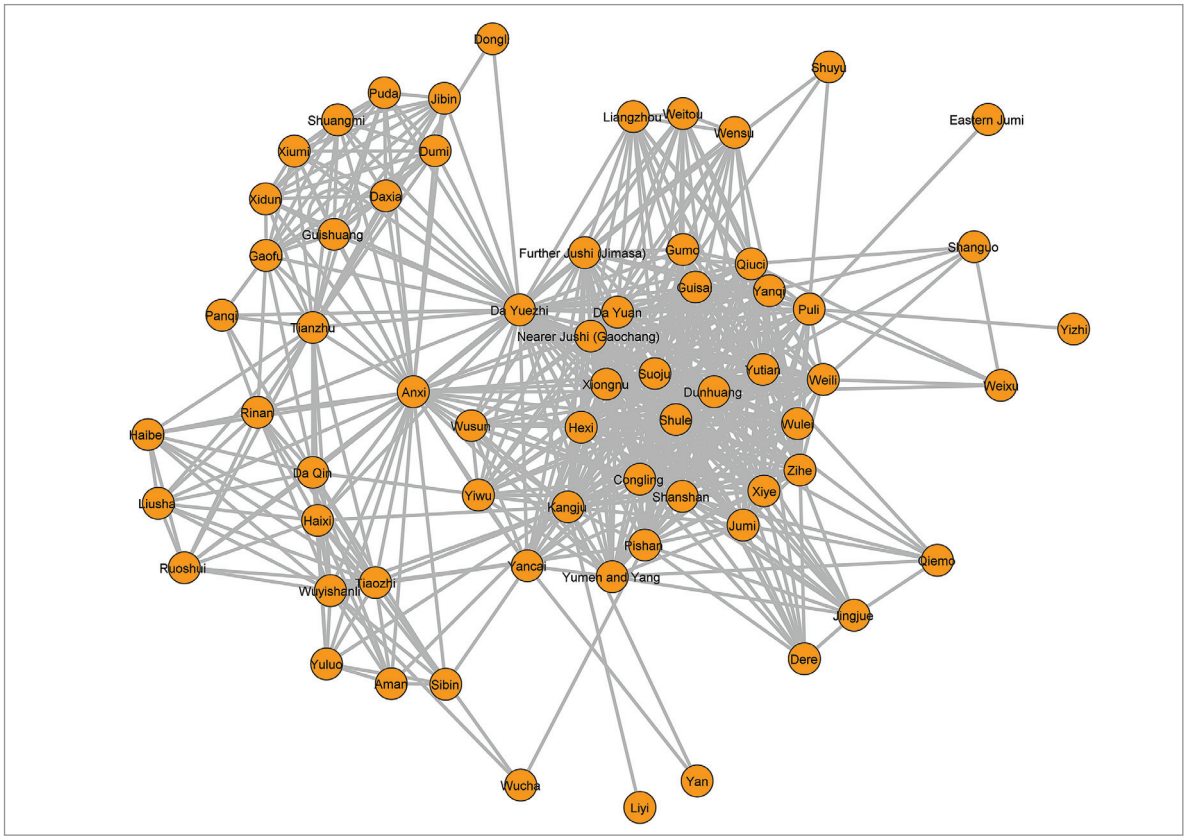

Fig. 4: The *Hou Hanshu* network model without Liuzhong and Louyang.

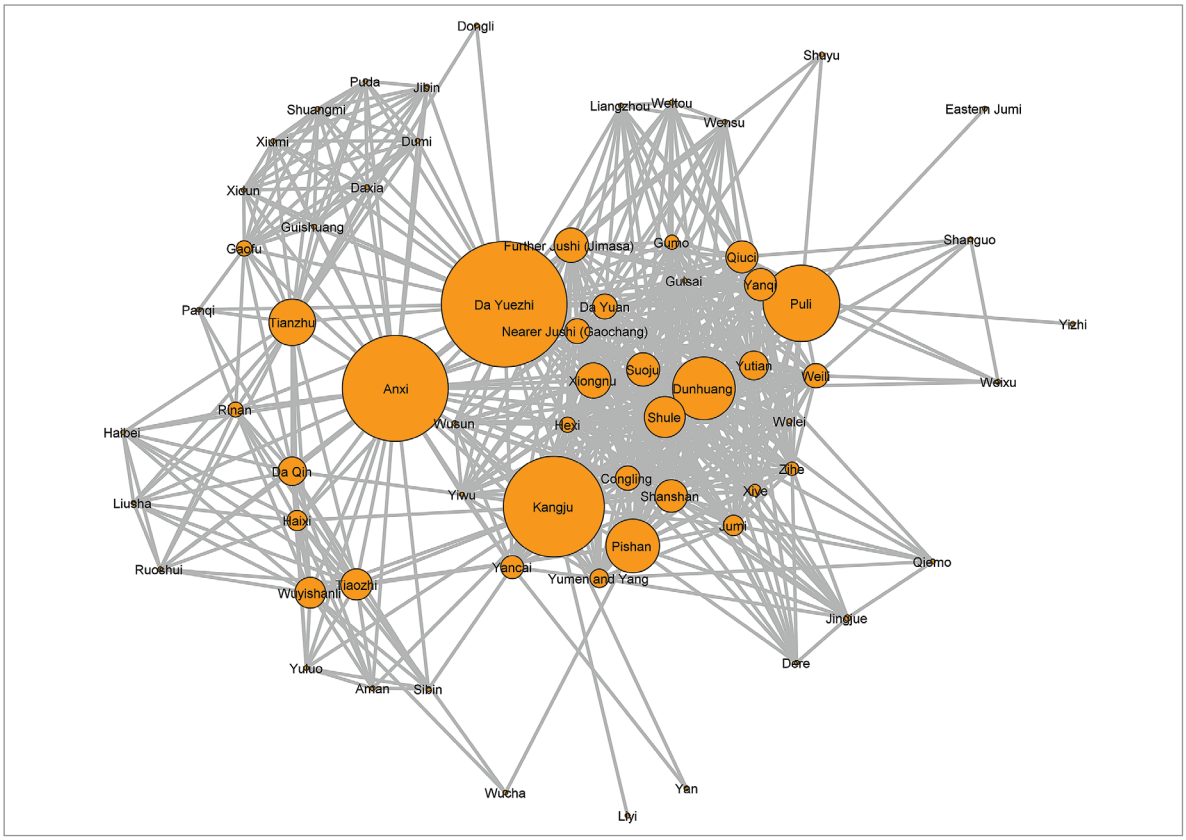

Fig. 5: *Hou Hanshu* betweenness centrality.

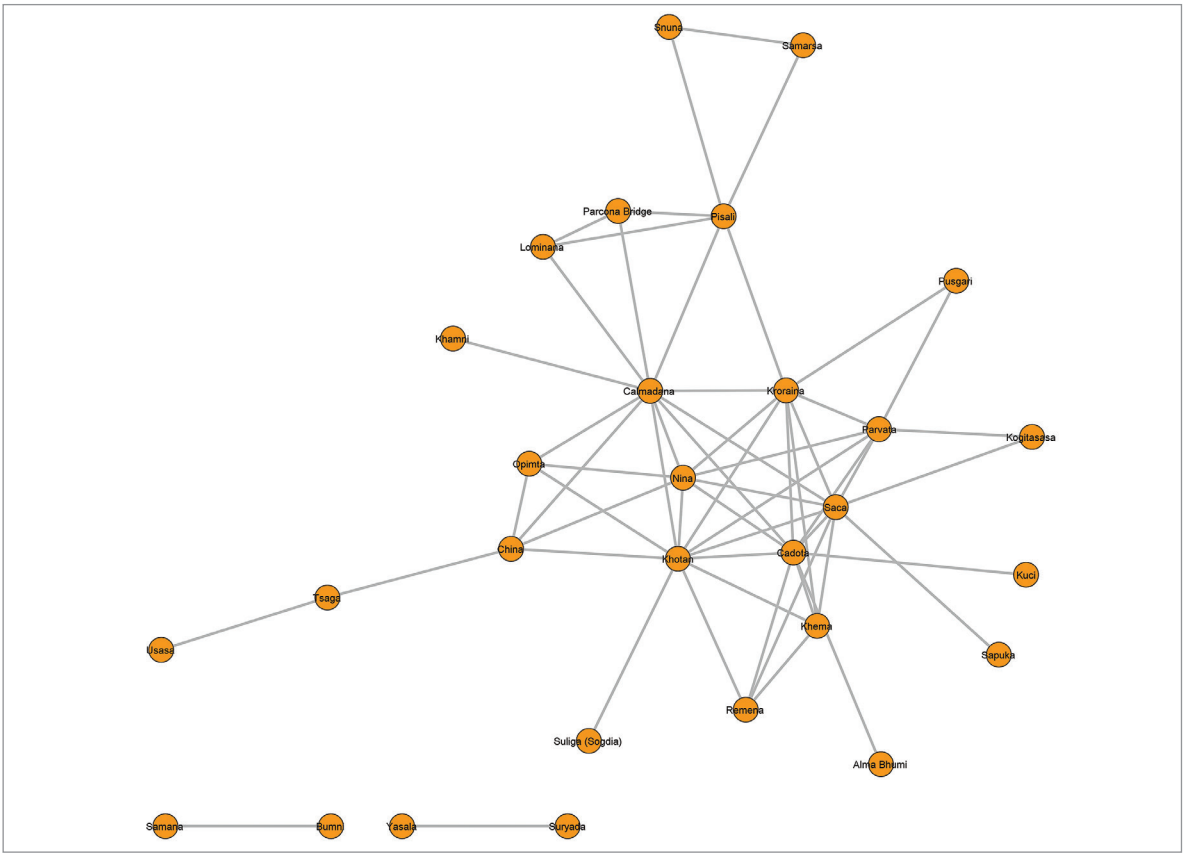

Fig. 6: The full Krorainan network model.

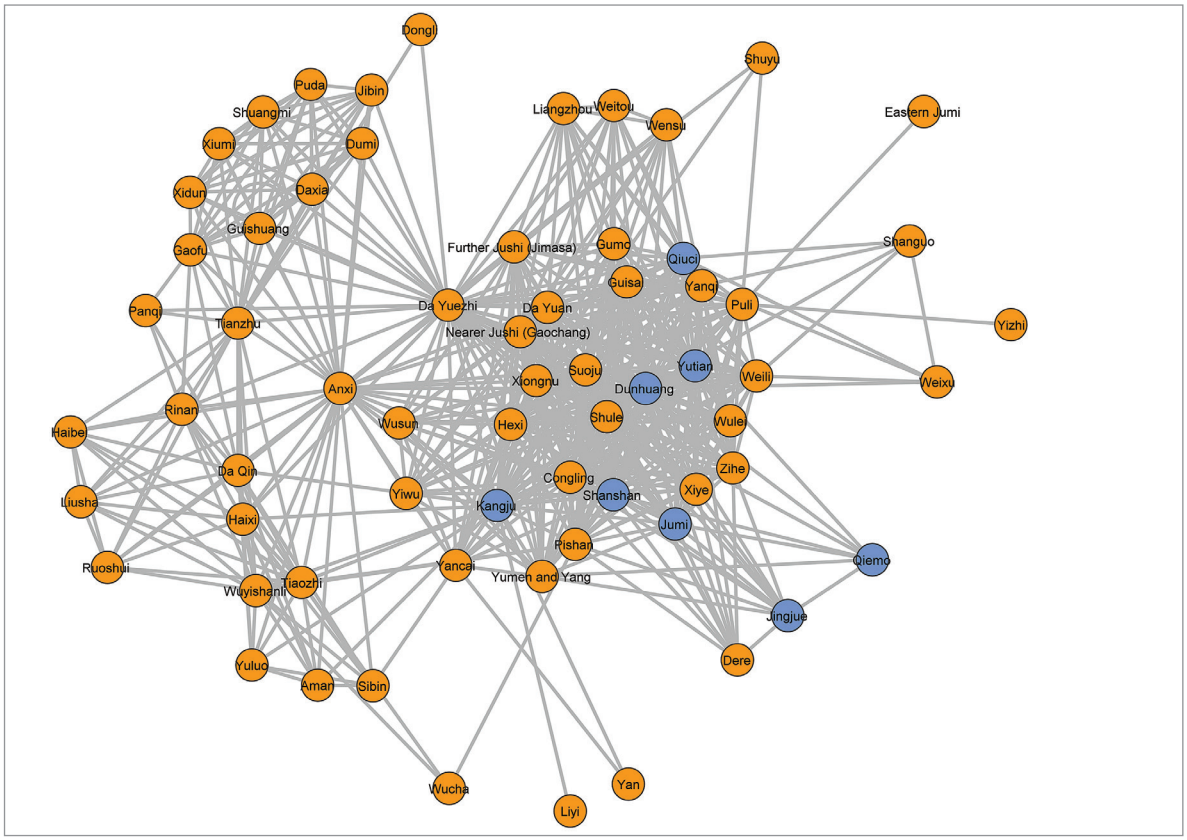

Fig. 7: *Hou Hanshu* network, overlapping nodes marked.

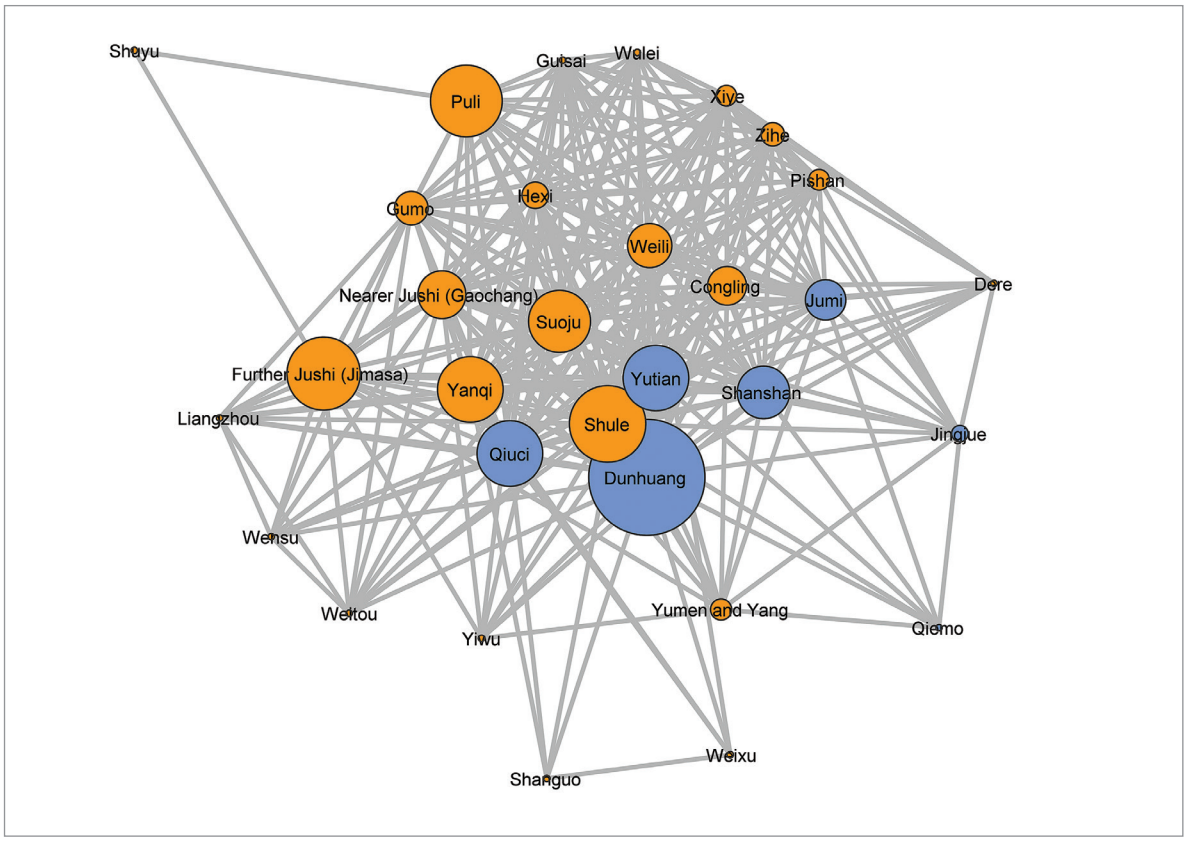

Fig. 8: *Hou Hanshu* model with only Tarim sites showing betweenness centrality.