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The Small World of the Vikings: Networks in Early Medieval Communication and Exchange

SØREN MICHAEL SINDBÆK

This study explores the potential of complex network theory as a new approach to the organisation and dynamics of communication in early history. It shows how network theory pins down shortcomings of existing archaeological conceptions of trade and exchange. Moreover, it supplies a series of new, relevant questions to this subject, and new models to guide their solution. Analysing two examples, the article charts the affiliations of persons and sites in the ninth-century literary description of Anskar's *vita*, and the distribution of artefact types in a large number of Early Viking Age sites in South Scandinavia. It shows how key features of complex networks can be outlined in a fragmentary sample of links. Viking Age long-distance exchange is shown to have generated a small group of hubs, but lacked another feature, typically found in mature, robust networks: the connections rarely reached across hierarchical levels. This made it vulnerable to systemic collapse, and points to a salient difference between early medieval long-distance communications and modern globalisation.

NETWORKS AND THE ARCHAEOLOGY OF EXCHANGE

Viking Age Scandinavia was a well-connected world. Wherever we turn in the archaeology of the period, we find evidence of communications over long or short distances: from towns and manors relying on supplies from a hinterland to things and people travelling on a continental scale. For example, North African coins are found in Central Sweden, a strap-end of Central Asian type turns up in Iceland, and Scandinavian brooches are discovered east of the Urals. Sea travel, invigorated by the introduction of the sail to the northern seas of Europe in the Merovingian period, carried exchange over wide areas. They linked Viking Scandinavia with Carolingian Europe and the Abbasid world system, the latter one of the most remarkable formations in Old World history.

This pervasive connectivity, more pronounced than in any previous period of Scandinavian history and archaeologically more perceptible than in most of early medieval Europe, has made the Viking period a focus of studies in ancient exchange (e.g. Näsman 2000, McCormick 2001, Verhulst 2002, Pestell & Ulmschneider 2003, Gustin 2004, Barrett *et al.* 2004, Hodges 2006). The geographical scale of contacts sometimes leads researchers to ask whether globalisation is a property restricted to the modern world. Was the Viking world any less international than our own?

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Cross-cultural encounters, which sustained long-distance contacts in this and other ancient networks of exchange, mostly took place in a few distinctive locations. Variously known as emporia, ports-of-trade, proto-towns or colonies, these are among the best-investigated archaeological sites from the Viking Age world. The records from these sites form a key to both the structure of connections and the actual cultural communication in a pre-modern precursor of global interaction. Often, however, these sites are studied in isolation from the very networks to which they were central. The models and theories applied to the study of these sites sometimes fit the subject less than perfectly.

Within the last few years, the growth of electronic communication, especially the Internet, has triggered a rapid development in the understanding of communication. The increasing availability of large, digitalised datasets has led to a series of pioneering studies that seek to analyse complex, interconnecting systems in terms of specific morphology, rather than mere cumulative trends. The underlying analytical techniques of graph analysis and multidimensional scaling have long been available, and have even been applied to archaeological problems. Now, however, these methods are applied to very large and complex systems from which a kind of statistical dynamics emerges.

The results have shown that several received assumptions about network organisation do not correspond with the observations made in real networks. The striking homologies observed in structures as different as neural networks, electric power systems, social groups, and the Internet have led authors to suggest a basic similarity in the architecture of networks, and to propose a series of new models to account for their properties (popular presentations by Barabási 2003, Watts 2003, recent summary in Newman *et al*. 2006).

Complex network theory has emerged as an amendment to statistical physics, aiming to describe features of biological, social or technological networks. Yet it provides ideas that are equally relevant to social, historical and cultural studies. As the application of network models has developed and matured, they have also begun to surface in historical and archaeological research (e.g. Ormerod & Roach 2004, Wells 2005, Evans *et al*. in press).

One area in which network theory has a significant contribution to make is in the study of ancient exchange and communication. Much of the criticism raised by recent network studies applies immediately to assumptions that have been basic to archaeological research in this field. They can be pointed out with reference to two well-known and frequently referred models.

In the *down-the-line* model, things are assumed to pass randomly from hand to hand from a source area towards more distant receivers (Renfrew 1977:77ff). This implies a network in which links are evenly or 'democratically' shared between the nodes. One of the most consistent findings of network studies is that such distributions hardly ever occur (Barabási 2003:63). Even in the absence of higher levels of organisation, we should expect exchange a priori to proceed chiefly between particular nodes, rather than randomly among neighbours. When an approximation of the predicted monotonous decrease pattern is sometimes observed in archaeological distributions, it is more likely a result of the averaging-out effect of changing practice and geographical distance, than an evenly distributed mode of exchange.

The basic inequality of sites, ignored by the down-the-line model, is described by the *central place model*, rooted in the geographical studies of Christaller (1966) and introduced in archaeology by Clarke (1972). Central place theory argues that aspects of distribution and control are restricted to a few sites, more or less widely spaced depending on the hinterland implied. This captures an important feature of most communication

and exchange but suffers from another basic defect pointed out in many recent studies of networks: it builds on an essentially static principle. The model tacitly assumes that the historical origin of a network will converge towards the state described. On the contrary, network studies have typically found that the formation process remains important for the network, giving certain nodes a robust priority and affecting the architecture of the network at large (Barabási 2003:91).

In short, the common archaeological models of exchange assume ancient exchange to have developed from a random, democratic basis, and to have grown into a static, a-historical equilibrium. In contrast, complex network theory suggests that details in the development and arrangement of connections were decisive for the robustness of systems, for the possibility of control, and thus for the historical development of exchange and communications. Simple as it is, this criticism concerns core features of the most widely applied models of exchange in archaeology, and applies regardless of whether the scale involved is regional or that of a world system.

THE DYNAMICS OF NETWORKS

In spite of the enthusiasm of some network researchers, who eye a new chance for a 'social physics', there is a leap between the study of technological or biological networks and human societies. Yet the chance of comparing 'incomparable' phenomena may put us on the track of new realisations. Drawing on the lessons from complex network studies, we can pose new questions and propose new models for their solution.

A particular property, which has caught much attention in network studies, is the 'small-world' paradox (Watts & Strogatz 1998). Most geographically-organised networks are highly clustered: neighbours link to neighbours, who in turn link mostly to the same neighbours, etc. In this situation, one will expect the path between two random nodes in a large network to be a very long one on average. Yet, many networks are shown to possess subtle topological features that create much shorter paths than expected. This is the essence of the often-repeated phrase that all people on earth are connected through less than 'six degrees of separation'.

In a historical and geographical setting like Viking-Age Scandinavia, a person or thing travelling exclusively from neighbour to neighbour would pass as many as ten links in order to travel a hundred kilometres. Dozens or even hundreds of links would have to connect before reaching, say, from the Rhineland to Sweden. Tests confirm that communication relying on social chains of such length is extremely unlikely to succeed (Dodds *et al*. 2003). Yet an abundant material testifies that things regularly did travel across remarkable distances in the Viking period. Items like Arabic coins or Frankish sword-blades are found throughout Western Eurasia, not as occasional rarities but as things that were once regularly available (see e.g. Steuer 1987). This strongly indicates that a small-world formation was in play. A small world does not warrant that a network can be easily navigated, as no individual knows but a fraction of the whole system, but it implies that news, innovations, viruses or even material objects may spread more directly than any single person can account for.

A small-world network can develop in a number of ways (Fig. 1). One model invokes occasional random links, or 'weak ties', that cross between otherwise distant nodes (Granovetter 1973, Watts & Strogatz 1998). But it appears that many small-world networks build on a different principle: they combine a small fraction of hubs having very many links with a large number of 'poor' nodes having very few. This has been called a scale-free architecture, as it combines nodes of entirely different scale (Albert & Barabási 1999).

The important point of these and other models is that the specific configuration of a

complex network has important implications for the dynamics and robustness it will allow. The structure of scale-free networks makes them robust against random failure, but vulnerable to attack directed at the hubs (Albert *et al*. 2002). This is particularly true if the net forms a hierarchy, as when sites beyond the hubs form local clusters, bridged with the rest of the network mainly through the hubs (Ravasz & Barabási 2003). Translated into an ancient exchange system, this would mean that the loss of an accidental site, e.g. if a farmstead was deserted, would have very little effect on the network at large. The sack or occupation of even a single major trading port, on the other hand, could have major implications for the whole system of exchange.

In Viking-Age Scandinavia, a small group of sites can be identified in which the number of external 'links', in terms of non-local objects, is much larger than in average sites. Imported domestic pottery or personal items, which may be assumed to have belonged to foreigners, are found with remarkably few exceptions only in this small group of hubs (e.g. Callmer 1998; Sindbæk 2007). These, unsurprisingly, are the sites which archaeologists point out as important trading-places. The few written sources of the period also suggest that a limited number of sites enjoyed a special status. In so far as hubs are defined broadly as sites of vastly different scale than the average, Viking Age exchange had such sites indeed.

The small-world phenomenon, whether created through hubs or weak ties, would seem an obvious explanation for situations in the past in which local clustering combines with long-distance contacts. But can we make this statement more than a mere assumption? The problem here is the lack of coherent, complex data.

Because of the fragmentary state of most archaeological and written data concerning early medieval Europe, a detailed quantitative analysis of any scale is unattainable. The interactions recorded in early written sources

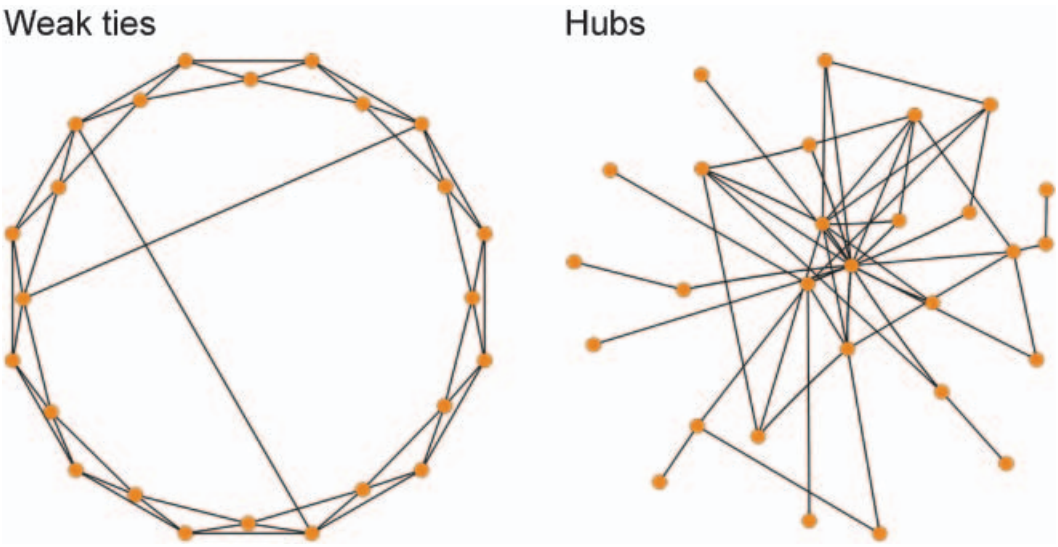

Fig. 1. *Two network structures, both of which generate a 'small-world' system with different forms of vulnerability: a locally clustered network with occasional random link or 'weak ties', and a scale-free network.*

and archaeological remains rarely suffice to map even the smallest social groups in their entirety. This could speak against the possibility of any form of network analysis, whether simple or complex. But might it still be possible to outline features of topology in a shattered record? Could we argue that the fragmentary samples, being exactly disordered and arbitrary, embody statistical properties of the much larger system of which they were part?

This question is explored in the following two examples, one issuing from a written source, and the other from archaeological data. The method employed is a conventional social network analysis, tracing the affiliations between a set of actors and events – in the present case a group of sites and the persons or things travelling between them (Wasserman & Faust 1994:291ff). The analysis breaks with conventions, however, in proposing that the results can be interpreted as the imprint of a complex communications network.

ANSKAR'S AFFILIATIONS

The first example builds on a text familiar to most students of the Viking period. The *Vita Anskarii* is one of the liveliest contemporary texts on Viking Age Scandinavia. Anskar, who died in 865, was the most significant Carolingian missionary bishop in the north. His *vita* was written by his successor, Rimbert, who takes a modest part in the events (cf. Palmer 2004). Rather than a historical document, it can be regarded as a ninth-century historical novel about events in the recent past. Even so, it reveals a network that gives plausible hints of the large-scale organisation of communications in the time and region concerned.

No less than 35 episodes of travel are explicitly mentioned in the text, even excluding the return journeys that can be inferred from the context. Still it is clear that these are only a fraction of the communications that take place around the main events. Reference is made on numerous occasions to foreign merchants, to sailors and slaves who people the ports and emporia, to passing trading vessels and pirates, to great assemblies and to news passed by anonymous messengers. The vast majority of the travels described are journeys into the missionary field (Fig. 2). Travel in connection with the numerous events that take place within the Carolingian realm is rarely described in the same detail. This leaves a very one-sided picture of the relations.

A richer and more instructive picture emerges if we part with the structure of the narrative and chart the association of sites by persons. The *vita* refers to a total of 22 sites as visited by 55 named individuals or groups, resulting in 116 relations, charted in the graph at Fig. 3 (see note 1). This does not include the biblical and historical persons and sites encountered in dreams. By the logic of the narrative they could be included, but they would form a cluster or 'island' of their

Fig. 2. *Map of the 35 journeys described in Anskar's* vita. *The exact routes shown between the sites represent educated guess. Sections travelled more than twice are shown in bold line, while the trunk route from Dorestad to Birka, travelled on more than 10 occasions, is emphasised in extra-bold.*

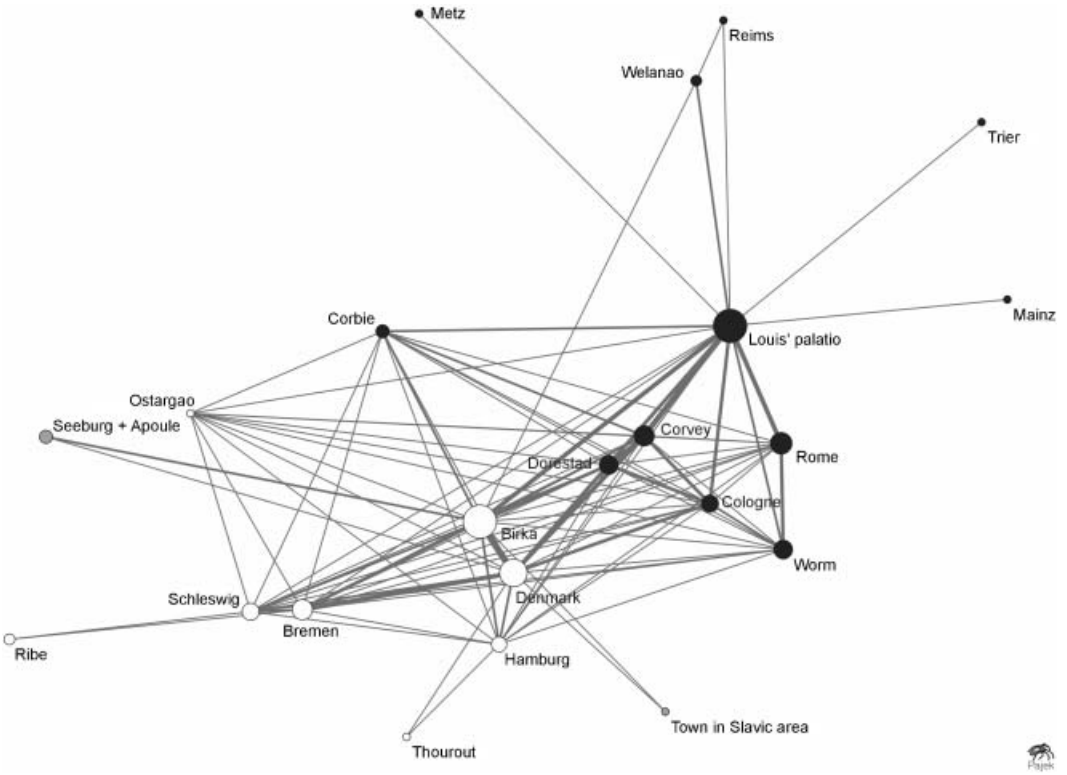

Fig. 3. *Graph of affiliations of 22 sites by 55 groups or individuals in Anskar's* vita*. The nodes are coloured to distinguish between sites belonging to the core of the Carolingian empire (black), the missionary frontier (white) or the world beyond (grey). The structure of communications unites the geographically dispersed emporia in the centre of the network.*

own, bridged to the rest of the diagram by the travels of Anskar only.

In the graph, two sites are linked if one person or group occurs at both sites. The size of the nodes corresponds to the total number of links they receive, that is to say, the number of persons or groups who visit them. The thickness of the lines corresponds to the number of persons or groups that two sites have in common, ranging from one to six. The sites are distributed in the two dimensions of the graph according to a calculation of their relative 'popularity'. This reflects not only the number of links a site receives, but whether links come from other 'popular' or more peripheral sites. The nodes are coloured to distinguish between sites belonging to the core of the Carolingian empire (black), the missionary frontier (white) or the world beyond (grey).

The sites are structured into three zones by the associations in Rimbert's narrative that are more social than geographical in nature. In the upper right half of the graph we find sites associated with the church or imperial court of the Carolingian empire. Anskar's missionary field fills in the lower left half of the middle, while the few sites in the heathen world beyond the Carolingian mission sprawl in the lower and left periphery. The centre of the graph is taken up by a grand cluster of sites linked by the hero of the story, Anskar. On one side of this cluster, the court of Louis the Pious acts as a bridge to a mostly separate orbit of ecclesiastical political centres, marked out by a number of

bishop's sees. In the core of the network we meet five particularly popular sites. One is Anskar's home monastery, Corvey; two others, Cologne and Dorestad, are geographically central 'road-stations' repeatedly encountered en route to other locations. The last two are more surprising perhaps: Birka, geographically the most distant site in the orbit, and 'Denmark', also in the periphery of the net.

A large part of the action, which is referred in the text to 'Denmark', can be assumed from the context to have occurred in the emporia Schleswig (Hedeby), or sometimes Ribe, both of which now turn up in the periphery of the graph. If we restore Hedeby and Ribe to the position of 'Denmark', we find that this literary account of the deeds of a Carolingian missionary places four of the largest trading centres of the Viking world as its communications hubs. The inclusion of Birka in this group is particularly striking. Although in geographical location and evidently in the literary perspective of the *vita* Birka is the far end of the world, it acts as a hub of events linked by numerous persons and groups to a surprising number of other sites.

If we proceed to characterise the network presented in Rimbert's text, there can be little doubt that it contained hubs: although the typical number of links for a site is one to four, two sites, Birka and the court of Louis the Pious, stand out as hubs with 19 links each. How 'large' or 'small' this world was is difficult to prove in a sample of such limited size. Yet we can see that the most common source of social distance, namely geographical dispersion and local clustering, will have been greatly reduced when hubs as distant as Birka, Cologne or Rome were only one step apart. But we also find hints that communications stretching over such distances were rare, or else they would not have counted as remarkable to be counted in the deeds of Anskar. Long-distance communications also seem to have been highly hierarchically organised since they repeatedly end in the same few sites.

Judging by the account of Anskar's *vita*, then, exchange in the Viking Age created a 'small' world held together by hubs, but structured as a vulnerable hierarchy with few connections across hierarchical levels. The *vita*, as already said, is a historical novel, but the structure of connections, as well as the status of the particular sites as hubs, is confirmed when we turn to the second example, built on archaeological data.

A MATERIAL WEB

If this reading of Anskar's *vita* is correct, communications take place in the core of a complex network. The large number of sites that must have formed the periphery of this network is hardly ever mentioned in this or other written sources. In order to approach these, we must turn to archaeological data.

During the past few decades, a large number of excavations have taken place in Viking Age settlement sites. In southern Scandinavia and northern Germany in particular more than 500 sites have been subject to excavations. Even though this includes many sites with indistinct features and scanty finds, enough remain to provide a basis for an archaeological investigation of communications in part of the area depicted in Anskar's *vita*.

The present analysis includes evidence from 72 excavations in 71 settlements (for details, see note 2). The sites form a deliberately mixed assemblage, comprising settlements from the Slavic, Frisian and Scandinavian cultural areas. They include the two emporia mentioned in Anskar's *vita*, Ribe and Hedeby, a selection of what are probably smaller markets (Vikhögsvägen, Ystad, Trelleborg, Åhus, Vester Egesborg, Århus, Gross Strömkendorf, Ralswiek, and Menzlin), some elite residences (Järrestad, Slöinge, Toftegård, Starigard/Oldenburg), and a large group of undistinguished village sites.

The chronological resolution of the material is generally low. Some sites trace continuity

from the late Merovingian period or into the late Viking Age. Important sites like Ribe or Hedeby only coexisted for some 50 years of their long history, and may essentially represent successive stages in the institutional history of exchange (cf. Theuws 2004). All of the sites selected, however, have evidence of activity in the early Viking Age, i.e. the first half of the ninth century. The chronological variance is further reduced by the range of artefacts selected, most of which comprise types characteristic of the early Viking Age.

The geographical distribution of the sites partly reflects original trends in settlement density, and partly variation in the rate of modern development and differences in research traditions (Fig. 6). The predominance of near-coastal sites very probably reflects locational preference. Yet inland regions were surely also settled, as confirmed by toponymic evidence. The lack of excavated settlements in some inland regions is largely due to a scarcity of modern development and hence archaeological fieldwork.

The 31 types of artefacts selected to indicate links are clearly identifiable items with a specific or restricted provenance and which are robust to different conditions of preservation and retrieval. Most of the types considered are so common that they can be expected to turn up in an assemblage of some size if they were present in the site investigated. They comprise various types of coins, ceramics, glass vessels and beads, as well as tools and refuse associated with various crafts (for details see note 3).

A shared artefact type does not show actual communication between sites, rather it indicates the existence of a group within which every site was connected to at least one other site. The same artefact type may be locally produced in one site and imported in another – very possibly from a third, unknown location. The lines of the graph, therefore, show both more and less than actual communications. More, because a shared type will inevitably affiliate a site with others with which it never had direct contact; less, because a single link may be the laconic trace of intimate, long standing relations. It will rarely be possible to account for any individual affiliation. But when a number of independent groups are compared, the cumulative picture may reflect authentic trends. In this perspective it matters less if a group of things represents a regional tradition of production or a regional pattern of receiving goods from another region. They equally reveal zones and boundaries of contact. As such, the links can be regarded as a condensed reflection of communications within a complex network.

The resulting network of 491 links is shown in Fig. 4. The network is generated in the same way as the one illustrating Anskar's *vita*. The position of a site reflects its relative popularity and affinity with other sites, while the size of the node corresponds to the size of the recorded assemblage, as measured by the number of shards of domestic pottery retrieved. Most sites contain a few thousand shards, but the numbers range from 224 shards (Mossby) to 100,000 shards (Ralswiek). To clarify the structure of this very dense network, the graph shows only links that are sustained by three or more items.

Once again, the centre of the graph is formed by a small group of intensively connecting sites. The largest hub is Hedeby, closely followed by Ribe – exactly the two sites already met in Anskar's *vita*. They are flanked by most of the local markets and elite residences. An interesting member in this group is the site Okholm, which is located a few kilometres outside Ribe and is suggested to have served as a wintering quarter for some of the Ribe craftsmen (Feveile 2001). The network illustrates two separate excavations in Okholm, conducted in 1968 and 1996 respectively. Only during the latter was sieving and metal detecting conducted. As can be seen, this increased the centrality of the site markedly, even though Okholm 1968 also turns up among the core sites. This should warn us that

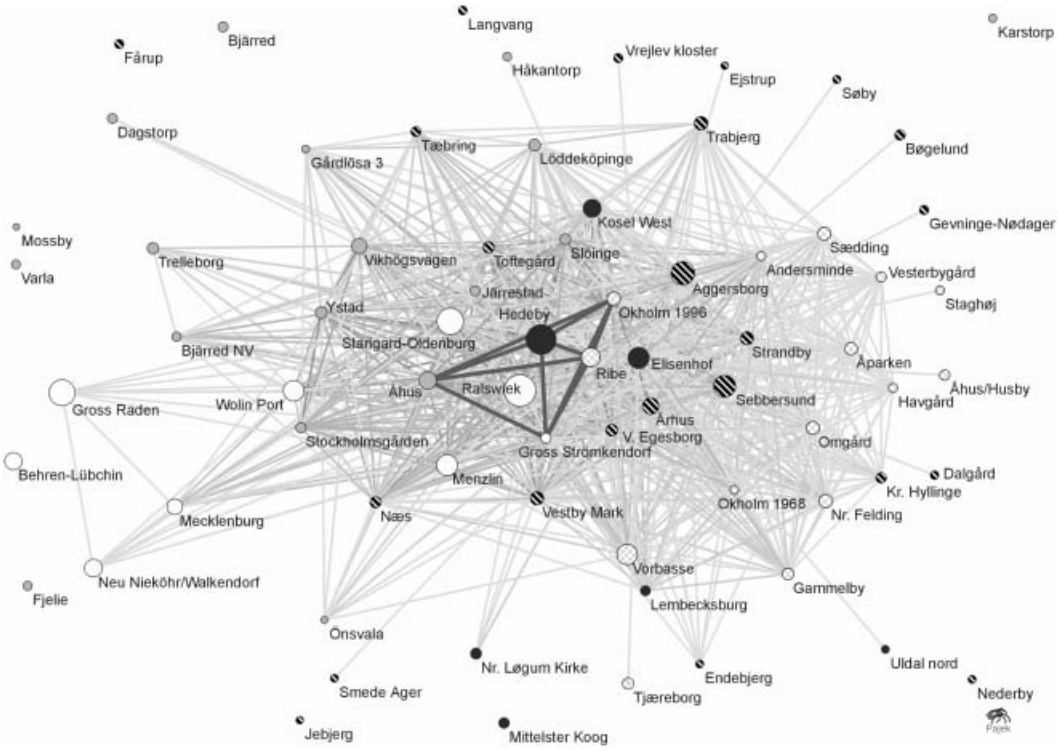

Fig. 4. *Graph of affiliations of 72 archaeological sites by 31 types of artefacts. The connections indicate shared artefact types, not actual movement between sites. The core of the network is a small group of emporia, whose exclusive connections are marked out in dark grey. Beyond the core, different colouring highlights geographical clusters. Data: see note 3 and 4.*

other intensively detected and sieved sites, e.g. Strandby or Vester Egesborg, may have received a too central position, while more crude excavations, like those at Menzlin or Ystad, are likely to have caused these sites to seem more peripheral than their true location in the Viking Age communications network.

In general, however, the data appear to contain robust structures. Though many small assemblages can be seen to fall on the periphery of the network, they often do so exactly because they are retrieved from small and doubtlessly peripheral settlements. It is important to note that there is no general correlation between the size of the assemblages and the centrality of the nodes. The investigation in Gross Strömkendorf, despite its very limited extent, still suffices to associate this site with the group of hubs. Gross Strömkendorf is commonly identified with Hedeby's predecessor Reric mentioned in the Frankish Royal Annals. Its position as a hub is confirmed by more recent, though not yet fully published, investigations (Jöns *et al.* 1997). Conversely, the very large excavations conducted in Gross Raden, Vorbasse or Trabjerg only confirm their status as rural sites with few external links.

The core of the network is the small group of emporia. Within their rich and varied assemblages, these sites share a small number of exclusive links, marked in dark grey in Fig. 5. They comprise ceramics

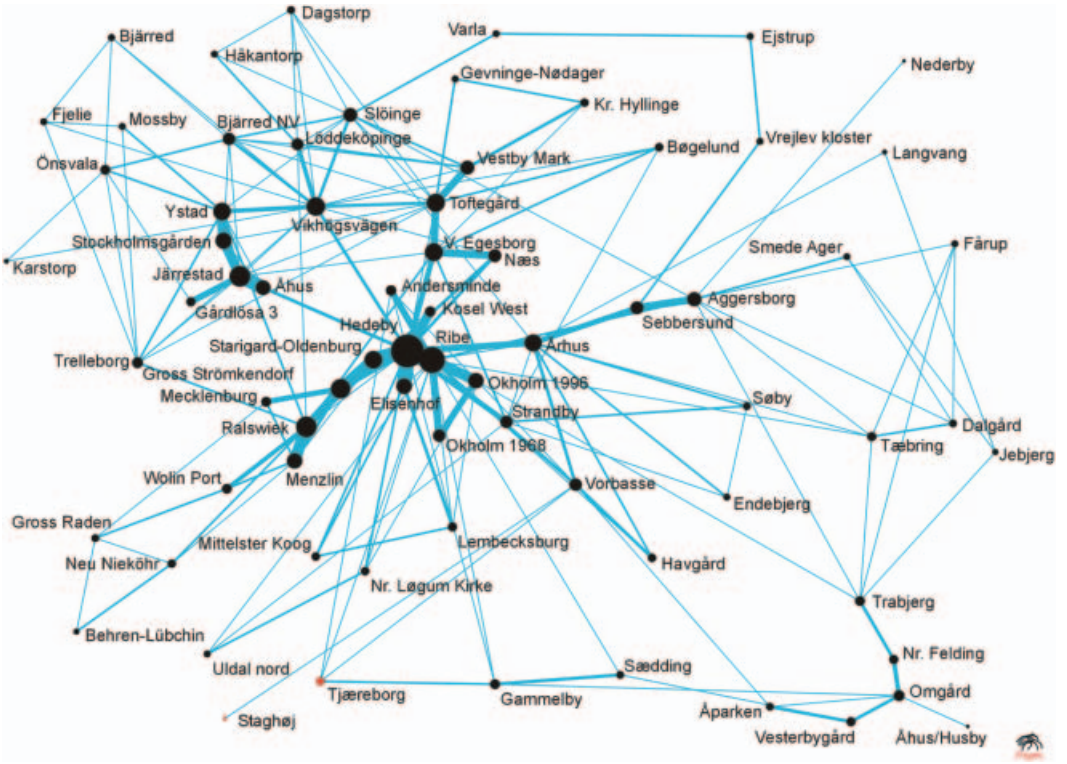

Fig. 5. *A re-modelling of the previous network, connecting each affiliation group by links through the nearest neighbouring sites. The resulting network shows a scale-free distribution of links in combination with a hierarchical and clustered topology.*

associated with foreign travellers and refuse from crafts with imported raw materials. Both are directly related to the role of these sites as stations of long-distance communication.

Beyond the core, the network displays a high degree of geographical clustering, highlighted in the graph by nodes of different colour: Mecklenburg-Vorpommern (white), South Sweden (light grey), East and North Denmark (hatched), Western Jutland (cross-hatched) and South Jutland (dark grey). The clusters form elongated 'pies', reaching from the core to the periphery as each region contains a few centres and many more peripheral sites. Between the sites in the periphery there are few or no connections, giving the network a star-shaped appearance.

Interpreting the graph as an impression of an underlying complex network, we can observe the same basic structure as appeared from the connections in Anskar's *vita*. Viking Age settlements in southern Scandinavia and the western Baltic region appear to have communicated as a scale-free network with a small number of hubs: Hedeby and Ribe have 29 and 24 links respectively, while the closest following site, Åhus, has 18. More than half of the sites have five or fewer links. The network very probably formed a 'small world', as each geographical region had some sites closely associated with the core. Moreover, the structure of relations was strongly hierarchical as few links reached between different clusters outside the core.

Fig. 6. *The same network as in Fig. 5 redistributed according to geographical location of sites on a map. The map does not represent an actual chart of communications but convincingly embodies the significant trends observed in the network. Local clusters are confined within defined settlement regions and united by links to the emporia along the principal coastal sailing routes.*

THE TEXTURE OF MOVEMENT

In some respect the previous graph gives a highly distorted vision of the relations it presents. Even if a group of imported items such as Rhenish basalt quernstones were all distributed from a single centre, the affiliation network will equally link every site in which they occur. In many cases, we may surmise that a shared artefact type within a group of sites represents far fewer communications than shown.

To interpret the data in terms of actual movement between sites, it is necessary to introduce assumptions about the direction of links for which the archaeological record rarely contains definite information. A provisional attempt may issue from the assumption that most affiliations were transmitted between neighbours. For imported items this assumption is certainly too conservative, supposing in fact a down-the-line system; but for many domestic objects like pottery and tools it is indeed a relevant assumption.

The graph in Fig. 5 remodels the previous network from this point of departure. It connects each affiliation group, or group of sites sharing a particular artefact type, by the smallest possible number of links that will join the entire group over the shortest possible distances: by linking each group through the nearest neighbouring sites. The construction shown does not consider geometrical distances, but estimated travel routes, giving priority to sea travel where

possible. This implies, for instance, that Århus (site no. 46) is considered closer to Hedeby (no. 59), to which it has easy maritime access, than to Ribe (no. 54), to which it is connected by a long journey over land.

The nodes in Fig. 5 are distributed according to the same popularity index as in the previous examples. The size of the lines is relative to the number of links between two sites, while the size of the nodes corresponds to the total number of links they receive. In this representation, the basic properties of the network pointed out above stand out even clearer: a scale-free distribution of links in combination with a hierarchical and clustered topology.

We may take the analysis one final step by redistributing the nodes according to their actual geographical location on a map (Fig. 6). The resulting map does not represent an actual chart of communications, as the sites analysed represent a fraction of the past settlement. The 'nearest neighbour' principle creates a bias towards local contacts. This is mediated, though, by the large number of artefact types included, as only some items will be present in other local sites. A further misrepresentation is that sites in the periphery of the investigated area receive a too marginal position, as only a part of their network is recorded.

Nevertheless the map reveals patterns that convincingly embody the trends observed above. Local clusters are confined within defined settlement regions. They are united by strong links to the major emporia along the principal coastal sailing-routes. Only occasionally are they bridged by links directly between the clusters.

CONCLUSION: DYNAMICS IN A SMALL WORLD

The examples analysed above indicate that Viking Age exchange in northern Europe formed a small world. It did so because it was focused on a small group of hubs, which gave it dynamic properties similar to a scale-free network.

On some points, the present investigation does not fully realise the potential of network analysis. The fact that only a single phase is analysed means that the dynamics involved are only hinted at. As was already mentioned, two of the largest sites, Ribe and Hedeby, though both very active in the early 800s, may ultimately belong to two successive stages of exchange relations. Better results might be obtained if we could analyse a series of successive phases. This would also enhance our interpretation of the individual patterns as trading networks might be compared directly with other trading networks rather than with abstract models. To realise this, however, vast amounts of further data will be needed.

Perhaps the most absorbing conclusion of this study is that early medieval Europe was a world almost as 'small' as the modern one. When Anskar went to Rome, he met the pope, a hub of all western Christianity. The pope personally appointed every archbishop, who in turn appointed every bishop who appointed every priest. If we can assume that every Christian knew a priest, this hierarchy would make Anskar affiliated to everyone in the vast empire of Louis the Pious through less than five degrees of separation. If Central Sweden was as tightly connected as we found southern Scandinavia to be, it is reasonable to assume that every farmer there knew at least one person who had travelled to Birka and met someone acquainted with Anskar. Following this trail, we would find a maximum of eight links separating a milkmaid in Uppland from a shepherd in Tuscany.

What then separates the Viking Age from the present world of globalisation? One important difference becomes apparent from the present investigation: the links, which sustained global connections, moved on an extremely narrow gauge. Communications across long distances were achieved through a spindly combination of hubs and weak ties. The number of large hubs was extremely

limited: we find the same few sites in the narrative of Anskar's *vita* and in the analysis of archaeological assemblages; the same, moreover, which are mentioned in the few other written sources from the period. Perhaps no more than a few dozen hubs like Birka, Hedeby, Dorestad or Rome linked all of Europe in the ninth century.

Moreover, it was mostly the same few groups of people who travelled recurrently between these sites. This, at least, is what appears from the tale of Anskar, but this is equally the lesson of countless other early medieval written sources in spite of the impressive number of travellers they record in total (McCormick 2001:270ff). Whether they were envoys, merchants or missionaries, most were specialised travellers somehow separate from the mass of society. Within this group, the road from Rome to Birka was swift. But beyond them, there were few if any links reaching outside local clusters.

The oft-celebrated global connections of Carolingian and Viking Europe, then, were held together by a tiny core of travellers, passing between an even smaller number of locations. While this network was sometimes remarkably effective, it was also extremely vulnerable. Often it took no more than the defection of a single node, sometimes a single person, for whole sections of the network to fall out. Several episodes in Anskar's *vita* describe how connections deteriorated dramatically if a key actor died. But even on the institutional level of ports and routes, it is evident how apparently successful emporia could be deserted within a few years if connections failed or reconfigured (Palmer 2003:50, Feveile 2006:52). The path from structure to collapse was never more than a few steps long.

The critical difference between the early medieval and the modern worlds was not the scale of connections but their pervasiveness, and hence robustness. The small world of the Vikings was able to generate remarkably far-reaching contacts, and sometimes to conduct extensive communications and exchange through these circuits. But it was rarely able to sustain them over long periods of time or in face of crisis.

NOTES

[1] The graphs illustrated in this article were generated using the software package *Pajek*, freely available from the website: http://vlado.fmf.unilj.si/pub/networks/pajek/defaults.htm.

[2] The position of the nodes is computed using the Kamada-Kawai algorithm (see Nooy *et al.* 2005). The calculations are sensitive to the starting position of the nodes, but the robustness of the features observed and illustrated here is confirmed by repeated tests.

[3] The analysis issues from 72 excavations conducted in 71 individual sites. In cases where other excavations have taken place in the same site, the one concerned here is specified in the list below. As a full list of references exceeds the scope of this article, sites are identified where possible by numbers in published catalogues, in which further references can be found. References to the catalogues are marked by M – Meier 1994; J – Jacobsson 2000; S – Sindbæk 2005. The sites analysed are: 1. Åhus/Transval (M 156); 2. Järrestad (Söderberg 2003); 3. Ystad/Tankbåten (M 146); 4. Stockholmsgården 1965–70 (M 150); 5. Gårdlösa 3 (M 157); 6. Mossby (J 135); 7. Trelleborg in Scania/Gröningen *et al.* (J 167); 8. Önsvala (M 119); 9. Karstorp (M 118); 10. Fjelie (J 108); 11. Bjärred 1966–99 (J 110); 12. Bjärred 2002 (Becker 2003); 13. Vikhögsvägen (M 109); 14. Löddeköpinge/1990 (J 82); 15. Håkantorp (M 106); 16. Dagstorp (Becker 1999); 17. Slöinge (Lundquist 2003); 18. Varla (Lundquist & Åhrberg 1997); 19. Vestby Mark (Ulriksen 1998); 20. Kr. Hyllinge (Arkæologiske Udgravninger i Danmark=AUD 1998: 111); 21. Gevninge-Nødager (AUD 2000: 95); 22. Toftegård (Tornbjerg 1998); 23. Bøgelund (Tornbjerg 1999); 24. Næs (Hansen & Høier 2000); 25. Vester Egesborg 1997 (Ulriksen 2006); 26. Strandby Gammeltoft (S 5), 27. Søby (S 3); 28. Endebjerg (S 1); 29. Vrejlev kloster (S 159); 30. Ejstrup 1986 (S 17); 31. Aggersborg (S 21); 32. Sebbersund (S 40); 33. Nederby (S 41); 34. Smede Ager (S 42); 35. Fårup 1975 (S 30); 36. Dalgård 1986–88 (S 30); 37. Tæbring (S 33), 38. Jebjerg (S 53); 39. Langvang/Voldum (S 59); 40.

Trabjerg (S 93); 41. Nr. Felding Kirke (S 99); 42. Omgård (S 92); 43. Åhus/Husby (S 98); 44. Vesterbygård (S 95); 45. Åparken (S 89); 46. Århus/Hotel Skandinavien (S 63); 47. Havgård (S 74); 48. Staghøj (S 121); 49. Vorbasse (S 122); 50. Sædding (S 117); 51. Tjæreborg (S 120); 52. Gammelby (S 111); 53. Andersminde 1980 (S 107); 54. Ribe/Posthuset 1990–91 (S 109); 55. Okholm 1968 (S 111); 56. Okholm 1996 (S 111); 57. Uldal nord (S 128); 58. Nr. Løgum Kirke (S 133); 59. Hedeby (M 167); 60. Kosel West (Meier 1994); 61. Lembecksburg (M 162); 62. Mittelster Koog (M 163); 63. Elisenhof (M 165); 64. Starigard-Oldeburg (Müller-Wille 1991); 65. Gross Strömkendorf (Wietrzichowski 1993); 66. Mecklenburg (Donat 1984); 67. Menzlin (Schoknecht 1977); 68. Ralswiek (Herrmann 2005); 69. Neu Nieköhr/Walkendorf (Schuldt 1967); 70. Behren-Lübchin (Schuldt 1965); 71. Gross Raden (Schuldt 1981, 1985); 72. Wolin/port (Stanisławski 2000).

[4] The following items are charted as links: 1. Muschelgrus ware; 2. Badorf-type ware; 3. Reliefband ware; 4. Tating ware; 5. Feldberg ware; 6. Middle Slavic ware; 7. swallow's nest vessels; 8. vessels with upstanding ear; 9. bossed cups; 10. steatite vessels; 11. Byzantine coins or seals; 12. Hedeby coins; 13. Arabic Dirhems; 14. Frankish coins; 15. refuse associated with bronze-casting (regular); 16. refuse associated with bronze-casting (occasional); 17. refuse associated with bead-making (regular); 18. refuse associated with bead-making (occasional); 19. refuse associated with comb-making; 20. refuse associated with amber-carving; 21. conical spindle whorls of baked clay; 22. symmetrically bi-conical spindle whorls of baked clay; 23. dome-shaped spindle whorls of sandstone with furrow-ornaments; 24. disc-shaped spindle whorls of red sandstone; 25. spindle whorls of steatite; 26. quernstones of Rhenish basalt; 27. quernstones of sandstone; 28. segmented glass beads; 29. gold- or silver-foil glass beads; 30. cut tubular beads; 31. glass vessels. For definitions, see Callmer 1977 (beads) and Lüdtke & Schietzel 2001 (ceramics).

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