Surviving Alliance Network Evolution during Industry Convergence: Observations and Future Research Directions

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How does the evolution of an industry alliance network affect firm survival? To address this question, we focus on alliance network evolution during a key event: industry convergence (IC) (Hsu and Prescott, 2016). IC is the blurring of boundaries between previously separate industries (Greenstein and Khanna, 1997). Our focus is important because an increasing number of industries are experiencing industry convergence (Kim, Lee, Kim, Lee, and Suh, 2015) and alliancing is an important adaptive mechanism (Lee, 2007) for addressing the challenges of IC where firm survival is in question. Adopting an inductive approach, we examined five snapshots of the evolving alliance network structure (Rosenkopf and Schilling, 2007) during the convergence of the telecommunications equipment and networking industries. As the structure of the network evolved, firms that created a diverse alliance portfolio were more likely to survive. Our findings support a weak version of network endogeneity (Gulati and Gargiulo, 1999) and IC as a boundary condition for the attachment logics of partner selection (Dagnino, Levanti and Li Destri, 2016) suggesting a pivotal role for firm agency during alliance network evolution.

Events stimulate the evolution of an industry's alliance network and subsequent strategic choices by firms further propel its evolution. Alliance network evolution is characterized by systematic and predictable response patterns to industry events (Madhavan, Koka and Prescott 1998; Rosenkopf and Schilling, 2007). Further, industry events have predictable consequences for network actors depending on whether the "shock" is structure loosening or reinforcing. Industry events that benefit incumbents and current industry leaders reinforce the existing alliance network structure. In contrast, events that disrupt current competitive paradigms loosen the existing alliance

network, weakening the positions of current leaders and allowing newcomers to move from the periphery to its core (Madhavan, et.al.1998).

The 'network in transition' perspective (Madhavan, et.al.1998) is important because it helps explain the fate of firms. The evolution of an alliance network provides opportunities for firms to strengthen or alter their network position and thereby their performance and survival opportunities. Research has demonstrated that firms occupying privileged positions in an alliance network experience positive outcomes including profitability, growth, knowledge transfer, preferred partners and innovation (Dagnino et.al, 2016; Granovetter, 2005; Koka and Prescott, 2008, Powell, Koput, and Smith-Doerr, 1996; Phelps, 2010),

The alliance network evolution literature has provided valuable insights into the antecedents, structures and outcomes of interorganizational networks (see Dagnino, et al., 2016 for a recent review). Building on these insights, we explore a complementary but different line of inquiry. We focus on alliance network evolution during a key event: industry convergence (Christensen, 2011; Greenstein and Khanna, 1997) and the role of alliancing in firm survival. During IC, the blurring of boundaries between previously separate industries creates new strategic opportunities, destroys competitive advantages while solidifying others, challenges cognitive maps and establishes new institutional arrangements (Burgelman and Grove, 2007; Katz, 1996) all of which have survival implications.

In this chapter, we examine three related questions. (1) When a structure-loosening event (i.e., industry convergence) hits an alliance network, how does the structure of the alliance network evolve? For this question, we draw on the typology of network structures (i.e., disjointed, hybrid, and spiderweb) proposed by Rosenkopf and Schilling (2007). Scholars disagree as to the strength

of network endogeneity and its effect on the stability of an alliance network structure (Gulati and Gargiulo, 1999; Rosenkopf and Schilling, 2007). In the case of a stronger form of network endogeneity once an alliance structure is established, actors may enter and exit but the overall aggregated structure remains intact. In the case of a weaker form of network endogeneity, the aggregate alliance structure changes over time as various actors exercise agency to shape and reshape the network. By examining five snapshots of an alliance network structure, we provide insights into the network endogeneity debate by showing that an industry structure-loosening event supports the weaker version of network endogeneity indicating an enhanced role of managerial agency.

(2) Do peripheral firms in the alliance network move to the center of the network because of the structure-loosening event? For this question, we draw on Madhavan, Koka and Prescott's (1998) network in transition perspective that predicts that a structure-loosening event provides an opportunity for peripheral firms to secure a more central position. In the network literature, attachment logics (Dagnino, et al., 2016) suggest that the rich get richer or that actors form partnerships with similar others. In contrast, a structure-loosening event perspective predicts that the poor can get richer and there are opportunities to partner with dissimilar others. Our findings suggest a more nuanced perspective. During the structure-loosening event, peripheral firms were able to move to the center of the alliance network but the original central firms were not driven from their central positions. In other words, the network's center of gravity (Gulati, Sytch and Tatarynowwicz, 2012) evolved to include peripheral firms suggesting a boundary condition on attachment logics during structure-loosening events.

(3) What role does alliancing play in firm survival during IC? The question of firm survival during alliance network evolution has taken a back seat to other firm outcomes (Dagnino, et al.,

2016) which is surprising given that evolution poses serious survival challenges. We advocate adding survival outcomes to the alliance literature because theoretically network evolution pose significant survival challenges (Madhavan, et.al., 1998). We found that alliancing was an effective adaptive mechanism to cope with the uncertainty of IC. However, as the extent of IC increased and the network evolved, alliancing negatively affected firm survival with the exception of those firms that increased their alliance portfolio diversity (more unique alliance partners): a contingency effect. Diversity of partners helped survival since it exposed firms to unique information and resources facilitating the entry into new product-markets. Managerial choices to alter their alliance portfolio to create a diverse set of partners weakens the effect of network endogeneity.

We adopted an inductive approach to studying our research questions for two reasons. First, given that the IC research context is in the nascent stage of development, we think that an inductive approach that allowed the data to speak to us was most appropriate for identifying observations that would lead to future theoretically driven research questions (Edmondson and McManus, 2007). Second, we wanted to examine our three research questions prior to and during the IC event to examine patterns as they unfolded. This allowed us to observe changes in the alliance network structure (i.e., disjointed, hybrid and spiderweb), if and how central and peripheral firms modified their positions, and patterns of firm survival (Rosenkopf and Schilling, 2007).

Our context was the IC between the telecommunication equipment and the computer networking industries. We make three sets of observations linked to our research questions. Using four-year alliance network structure snapshots, we observed that that the alliance network structure evolved from a disjointed structure to a hybrid structure and back to a disjointed structure as the IC event winded down. Second, we observed that peripheral firms in the network were able to move to the center but 50% of them exited the industry suggesting a 'peril of moving to the center'

phenomenon. We also observed that the hybrid network structures exhibited characteristics of attachment logic and saturation effects (Dagnino, et al., 2016). Our third set of observations focused on the role of alliancing in firm survival during the IC event. We observed that alliancing increased the likelihood of survival but in complex ways involving an interaction with alliance portfolio diversity. Our set of observations adds to the growing but nascent body of network structure evolution literature at the nexus of how events and alliancing impacts firm survival.

In the sections that follow, we first provide the contextual background of our study. We then report observations for the three research questions. We conclude the chapter with suggestions for promising research directions.

Theoretical Contextual Background: IC as Events and Network Structure Types

Two theoretical boundary conditions form the context for studying alliance network structure evolution during IC. First, we conceptualized IC as an event (Morgeson, Mitchell and Liu, 2015) that can be structure loosening or reinforcing (Madhavan, et al., 1998). Second, Rosenkopf and Schilling's (2007) typology of alliance network structure (i.e., disjointed, hybrid, and spiderweb) allowed us to observe if and in what ways an alliance network structure evolved during IC.

Industry Convergence as Events

Industry convergence (IC) is the blurring of boundaries between previously separate industries creating competition among firms that previously had not competed with one another (Katz, 1996). The primary antecedents of IC are a combination of changes in technology, government policies, customer preferences and firm entrepreneurship (Hsu and Prescott, 2016). For example, the convergence between the energy and IT industries is driven by advances in

technology that is adding intelligence to energy networks, government policies that incentivize the smart grid and the publics' desire for sustainable energy (e.g. Byun, Cho and Lee, 2009). The combination of IC antecedents affect interdependencies between industries that have implications regarding the form of IC. Two major forms of IC (Greenstein and Khanna, 1997) are *complementarity*, where two industries' products work better together such as the convergence of IT and automobiles and *substitution*, where buyers perceive the industries' products as interchangeable such as internet streaming versus cable TV. IC as an event creates significant uncertainties for firms stimulating problematic search for adaptive solutions (Cyert and March, 1963).

Conceptualizing IC as an event has significant implications for establishing the contextual boundary of alliance network structure evolution. In other words, we need a theoretical approach to the study of events. Building on systems theory, Morgeson, et al. (2015) proposed event system theory (EST) that focuses on "dynamics, change and system interrelationships" (p. 515). EST draws a distinction between the enduring and stable features of organizations and their environment and the role of events in stimulating change in behaviors, features or subsequent events. Events are a catalyst for change and are defined as external (in the sense that they are discrete observable actions or circumstances rather than unobservable internal psychological processes), bounded in time and space and involve the interaction of different entities (i.e., behaviors, features or other events) (p. 520). The strength of an event is positively associated with the extent to which it triggers action. Three characteristics that that determine the strength of an event are its novelty (new or unexpected), disruption (amount or degree of change) and criticality (degree of importance).

We posit that when the strength of an IC event is strong it triggers an evolution in the structure of an alliance network as an adaptive mechanism for addressing uncertainty and industry change. Madhavan et al. (1998) provided insights as to the direction of the evolution of the alliance network structure. Their insight was recognizing that events provide occasions for change in the structure of an (alliance) network. Their framework focused on whether central or peripheral firms were motivated to initiate and subsequently benefit from an event. When an event reinforces existing competitive dynamics, it strengthens the position of central network players and classified as a structure-reinforcing event. Central players are motivated to initiate change and benefits from it. In other words, the rich get richer. On the other hand, when an event disrupts existing competitive dynamics, it provides an opportunity for peripheral players to initiate change and subsequently benefits those players. This condition, classified as a structure-loosening event changes the balance of power in an alliance network; the poor get richer.

As a process, IC event unfold over a considerable period of years making it conducive for studying alliance network evolution. Examining U.S. high-technology industries using co-occurrence news article data at the 3-digit SIC level from 1987 to 2012, Lee, Kim, Kwak, Kim, Soh and Park (2016) found heterogeneous diffusion patterns for convergence. For some industries such as the general industrial machinery (SIC 356) and household cleaning and cosmetics (SIC 284), convergence occurred rapidly in approximately nine years and stagnated. In contrast, the industrial organic chemicals (SIC 286) and drugs (SIC 283) industries had a relatively low level of convergence over the 26 years of their study. A second characteristic of the IC process is that it results in semi-convergence where niches from the converging industries do not converge (Hsu and Prescott, 2016). For example, in the 15-year convergence of the analogy and digital camera industries, analog niches exist in the amateur (e g., instant) and commercial segments. Since IC

events involve a considerable number of years, it provides an ideal context for studying how the evolution of an alliance network affects the prospects of firm survival.

In sum, IC is an event that when of sufficient strength results in the evolution in the structure of an alliance network. An IC event can be structure reinforcing or loosening depending on if it reinforces or disrupts existing competitive dynamics. Firms use alliances as an adaptive mechanism to address uncertainties associated with an IC event and thus set in motion evolution in the alliance network structure. Thus, EST and the networks in transition perspective are appropriate lens for studying alliance network structure evolution because they focus on "dynamics, change and system interrelationships" (Morgeson, et al., 2015, p. 515).

Typology of Alliance Network Structures

Most research on network structure has focused on how network features such as centralization, structural holes and the small world problem affect a variety of outcomes (Madhavan and Prescott, 2017). Rosenkopf and Schilling (2007), in contrast, made a significant contribution by developing a typology of network structures based on a variety of network features. A central assumption of their research was that alliance networks structures can be classified into a few types and that technology characteristics of industries explain why particular industries exhibit a specific alliance network type. They identified three types of alliance network structures; disconnected, hybrid and spiderweb. Disconnected structures have few alliances and few connections among industry players. In contrast, spiderweb structures exhibit many alliances, a dominant cluster and a high degree of connection among industry players. Between the two are hybrids that have moderate levels of alliancing, clustering and connections.

Rosenkopf and Schilling's (2007) typology was developed using cross-sectional data and did not focus on network structure evolution. However, as they suggest; "An ideal study would include network snapshots at several times over the lifecycle of an industry" (p. 205). For our purposes, we slightly modified their suggestion. We examined alliance network snapshots during an IC event. This allowing us to observe the evolution of the alliance network. We further examined how alliancing affected a firm's likelihood of survival. Few studies in the alliance stream of research have focused on survival and none to our knowledge provided observations linking an IC event, the evolution of alliance network structure and its impact on firm alliancing and survival (our three research questions).

Data and Method

We selected the telecommunications equipment industry (circuit switching) (SIC 3661, 3663, and 3669) that converged with the computer networking industry (packet switching) (SIC 3576) as our empirical context (Eugster, Besio and Hawn, 1998). Our sample included 419 firms (305 equipment and 114 networking). Using a variety of sources including Thompson Financial SDC, Compustat, CorpTech Directory, Lexis-Nexis, company annual reports, websites, and industry documents we identified 370 alliances, firm entry and exit, compound average industry growth rate, managerial attention to the event, industry uncertainty, the extent of IC, and a variety of firm level data for the survival analysis. Figure 1 shows a timeline and summarizes entries, exits, alliancing activity and other pertinent data related to our context.

We were careful that our data conformed to the theoretical contextual established above. Specifically, the two industries are a recognized case of a substitution form of IC and can be classified as a structure loosening event (initiated by peripheral players) (Hsu and Prescott, 2016;

Lee, 2007). The IC event occurred in 1989 when the Internet-protocol-based technology (packet-switching technology) (e.g., Cisco, 3Com) started to subsume the technological base (circuit-switching technology) in the telecommunication equipment industry (e.g. Nortel, Nokia). The event essentially ended in 2003 when industry players focused on a new event involving next generation video technology (OECD, 2008). Finally, to examine the evolution of the network structure and consistent with alliance research on the duration of alliances (Phelps, 2003, 2010) we created four-year alliance network snapshots beginning with a 1988 pre-event snapshot and four IC event snapshots (1992, 1996, 2000 and 2004). Each snapshot contained only those alliances formed during that specific four-year period.

To ensure that our research setting conformed to the theoretical contextual background and to eliminate important rival explanations, we took several steps. We established that a substitution effect occurred between the converging industries, that there was considerable industry uncertainty, that industry life cycle effects did not drive our observations, that managerial attention was directed towards the IC event and that the two industries converged.

To confirm a substitution effect, using the CorpTech Directory database we calculated the number of firms operating in the circuit switching (equipment) and packet switching (computer networking) product-markets during our study period. The results (available from the authors) confirmed that the number of firms in the circuit switching market was initially smaller than the packet switching market, but surpassed it after 1991 and expanded across the years, suggesting a substitution effect. The substitution form of IC is particularly pernicious because it has the potential to eliminate a firm's markets creating uncertainty that stimulates problematic search for adaptive solutions (Cyert and March, 1963) such as alliancing to acquire capabilities necessary to compete in the converging industries.

Since uncertainty underlies the logic of event system theory, we measured environmental uncertainty in "demand" by regressing industry sales on time, obtained estimated coefficients, and then used the standard errors of the regression slop coefficient divided by the mean to capture the volatility of industry sales (Dess and Beard, 1984; Milliken, 1987). The average of industry sales volatility across the sample period was 12.8% suggesting considerable environmental uncertainty.

An alternative explanation for our observations is that the industries experienced the prototypical industry life cycle (i.e., growth, maturity, decline) during our study period. To address an industry life cycle effect, we calculated the compound average growth rate in sales between 1986 and 2006 and found it to be 13%. The industries grew at a strong pace and were in the growth phase of an industry life cycle. Thus, our observations are not subject to changes in the life cycle of the converging industries.

EST asserts that for an event to have salience it needs to have sufficient strength to warrant attention from entities. As a proxy for salience, we measured managerial attention toward IC. We located 746 CEO letters from 149 firms and constructed a list of IC keywords classified into three groups: technology-related, product-market-related, and convergence. To create a normalized measure of managerial attention to IC, we divided the number of key words identified in a CEO shareholder letter by the total number of words in the shareholder letter (Nadkarni and Barr, 2008). We calculated attention as a three-year decaying stock variable to capture attention during a window of time (Eggers and Kaplan, 2009). Figure 2 shows that CEO attention rose steady from 1990 to its peak in 1994. Entry and exit of firms is another indicator of attention (Figure 1). In 1996, exits from the industry exceeded new entrant and remained so for the remaining years of the study. Over the study years, there was a net entry of 39 firms (207 entrants – 168 exits). Forty percent of the firm exited (168/419) during the study period, 72% of which were via acquisition.

To establish that the two industries were converging we used the CorpTech Directory database to develop an extent of IC measure. Following Li and Greenwood (2004) we operationalize a yearly extent of IC as the average number of firms in voice-data product pairs (i.e. corresponding to the equipment and networking industries respectively) based on the logic that the extent of IC is determined by the relatedness between the two industries product-markets (Greenstein and Khanna, 1997). As the number of firms entering voice-data product pairs increased, the extent of IC increased. The CorpTech Directory database listed 65 product lines for the two industries (37 for computer networking and 28 for telecommunication equipment). Figure 2 shows that the extent of IC rose steadily and peaked at 0.49 in 2001. Examining the attention and extent of IC timelines show that attention preceded IC, which is expected. That is, managers are likely to enter cross-industry product-markets when they are paying attention to IC.

*** Insert Figure 1 and 2 about here***

Having established our context and eliminating important rival hypotheses, we now turn to examining the evolution of the alliance network structure in the converging industries. Alliances are viable adaptation mechanisms during IC especially since they are less vulnerable to time compression diseconomies and self-inertia forces compared to internal development (Lee, 2007; Tripsas and Gavetti, 2000). Our approach was twofold. We used timeline analysis to examine the five alliance network structure snapshots to develop observations as to the evolving network structure including some key features of the networks consistent with EST. These observations provide insights into two of our research questions; how does the structure of the alliance network evolve using Rosenkopf and Schilling (2007) typology and do peripheral firm become more central in the alliance network as conjectured by Madhavan, et al. (1998). We then conducted a Cox

Model (robust) regression survival analysis to address our third research question to observe the role of alliancing in firm survival during IC.

Observations of Alliance Network Structure Evolution

The organization of our observations is by our research questions. For each question, we identify the core research observation, discuss how we arrived at the observation and frequently offer future research directions.

Research Question (1): When an (structure loosening) event (i.e., industry convergence) hits an alliance network, how does the structure of the alliance network evolve? We observed that the structure of the alliance network evolved from disjointed to hybrid and back to disjointed. Figures 3 – 7 show the alliance network snapshots and related information.

In line with EST, we examined several features of each alliance network snapshot to observe how the IC event affected network structure evolution. Table 1 provides information for the type and features of the five alliance network snapshots. Our intent was not to replicate but rather apply Rosenkopf and Schilling's (2007) typology to our network snapshots and context. Thus, we selected features that helped us determine the type (disjointed, hybrid, spiderweb) of network structure for each snapshot as well as to draw observations about the overall pattern of network structure evolution.

The structure of the alliance network evolved from being disjointed prior to the IC event in the 1988 snapshot to a hybrid structure in the 1992, 1996 and 2000 snapshots and back to a disjointed structure in 2004 as the event winded down. These observations are judgements based on comparing the features of the snapshots with Rosenkopf and Schilling's (2007) typology and examples in their article. Clearly, the 1988 and 2004 snapshots exhibited the characteristics of a

disjointed network. Network centralization, an indicator of whether some firms in a network snapshot had many more alliances was very low. While network centralization is higher in the 1992, 1996 and 2000 snapshots, it is still low. None of the snapshots exhibited the characteristics of a spiderweb where there is an identifiable main cluster to the network. Rather, these three snapshots contained several hybrid network clusters characteristics. During an IC event, this is not surprising since there are a wide variety of strategic approaches: some firms being generalists while other specialize in niches. We more fully describe the network clusters as part of research question 2.

In the network snapshots, it is important to recognize that firms with no alliances during a snapshot are not shown in the figures. A couple of important features of the networks that aid in identifying network type are the size of the alliance network and the alliance participation rate (Table 1). The number of alliances in the hybrid structures (74, 145, and 92) are much higher than the disjointed network structures (30 and 29). Alliance participation rate is the number of firms with at least one alliance divided by the total number of firms in the alliance network. The participation rate for the two disjointed networks was 16% while the participation rate for the 1992, 1996 and 2000 networks were 21%, 38% and 32% respectively.

The networks snapshots are evidence that the structure of the alliance network evolved over the course of the IC event. We were surprised that the 2004 network was disjointed. Given that another round of IC was on the horizon involving video streaming, we expected that the 2004 network structure would involve many alliances. One plausible conjecture leveraging an analogy from the 1992 network (4 years after the IC event), is that industry participants wait a few years before adopting alliancing as an adaptive mechanism when faced with an IC event. A second surprise was the rather limited role of alliancing as an adaptive mechanism for most industry

participants reflected in the number of isolates as well as the alliance participation rate (Table 1). We conjecture that the isolates used internal development and possibly acquisitions as their primary adaptive mechanisms. We will return to this topic in the survival analysis.

Research Question (2): Do peripheral firms in the alliance network move to the center of the network because of the structure-loosening event as predicted by the network in transition perspective? (Madhavan, et al., 1998). We observed that by 1996, some of the peripheral firms in the two earlier network snapshots moved to the center supporting Madhavan's, et al., (1998) thesis. However, we also observed that four of the eight peripheral firms that moved to the center exited by the end of the 2000 snapshot. We labeled this observation 'the peril of moving to the center'. Studying the mechanisms that explain this concept would be a promising research project. Finally, the governance of the hybrid networks snapshots showed signs of attachment logics and saturation effects (Dagnino, et al., 2016).

To examine question 2, we used the 1992, 1996 and 2000 snapshots because the 1988 snapshot was prior to the IC event and by the 2004 snapshot the IC event was winding down. Both the 1988 and 2004 alliance networks were disjointed alliance networks where centrality has less meaning. Further, the number of alliances in the 1988 and 2004 snapshots was limited being 30 and 29 respectively. UCINET was used to calculate degree centrality for all firms in each of the snapshots. We used degree centrality because it is a measure of access to information and other flows of resources through a network. Given that uncertainty is high during IC, access to information is an important benefit of a central position.

Our approach was to identify two sets of firms: central firms and peripheral firms that moved to the center. Wave 1 (Central firms) were those that occupied central positions in the 1992

snapshot and remained central through the 2000 snapshot. They were central in the early years of IC and remained central as the IC event winded down. The seven Wave 1 firms were from the telecommunication equipment industry (Motorola, Nortel, Siemens, Qualcom, Ericson and Alcatel) apart from Cisco that was in the computer networking industry (see Figure 4). Wave 2 firms were peripheral in 1992 but became central in the 1996 snapshot and remained central through 2000. Of the eight Wave 2 firms, five were from the equipment industry (Lucent, US Robotics, ADC Telecommunications, Newbridge Networks and Nokia) and three (3Com, Dialogics, and FORE Systems) were from the networking industry (see Figure 5). Our approach was conservative in the sense that firms needed to have consistently high levels of degree centrality to be Wave 1 or Wave 2 firms. In each of the snapshots, the Wave 1 firms are circles and the Wave 2 firms are diamonds.

The evidence was consistent with Madhavan, et al., (1998) network in transition thesis that a structure-loosening event provided opportunities for peripheral firms to move to the center. However, we also observed that Wave 1 firms who were central in the 1992 snapshot remained central through the 2000 snapshot. In other words, when a structure-loosening event occurs central firms are not necessarily driven from their central positions.

Given our interest in survival during an IC event, we examined the survival rates of the Wave 1 and 2 firms. We observed what we label "The peril of moving to the center". Four of the eight peripheral firms that became central in the 1996 snapshot exited by the end of the 2000 snapshot. The four were US Robotics (acquired by 3Com), Newbridge Networks (acquired by Alcatel), Dialogic (acquired by Intel) and FORE systems (acquired by GE then Marconi). None of the seven Wave 1 firms exited during our study period. This observation provides a "performance" extension to the network in transition perspective. While a structure loosening

event provides opportunities to move to the center of an alliance network, whether and how it benefits those firms needs additional theorizing.

Dagnino's, et al, (2016) synthesis of the interorganizational network evolution literature provided us an approach for a qualitative assessment of network evolution that links research questions 1 and 2. The focus of research question 1 was on an exogenous IC event that drove the evolution of the alliance network while research question 2 provided insights into the endogenous role of central and peripheral firms in the intentional governance of network evolution.

After the exogenous IC event hit the alliance network in 1988, by 1992 lead organizations (Wave 1 central firms) had created an emerging small-world structure characterized by local clustering and high network reach. An important implication was that information and knowledge was flowing to and from the Wave 1 firms as they made sense of the IC event. Specifically, Wave 1 firms such as Nortel, Motorola and Cisco had formed local clusters (Figure 4). In the 1992 snapshot, the global reach of Wave 1 firms was evident in that 76% of the 70 firms with alliances were in direct or indirect contact with a Wave 1 firm.

By 1996, the hybrid network structure showed an increase in local clustering with Wave 2 firms (peripheral firms) such as Lucent and US Robotics forming local clusters while Qualcomm, a Wave 1 firm, increasingly formed its own local cluster (Figure 5). The global reach within the 1996 snapshot was very high where 74% of the firms with alliances were either in direct or indirect contact. While it is somewhat speculative, the hybrid network structure with local clusters and high network reach was evidence that the evolution of the network from 1988 through 1996 was partially driven by attachment logics (Dagnino, et al., 2016). We observed network cohesion (direct and indirect ties leads to future ties), preference for prominence (preference to ally with

central players) and structural homophily (firms with similar centrality form ties with each other). In other words, the center of gravity (Gulati, Sytch and Tatarynowwicz, 2012) within the network had evolved to include Wave 2 firms and attachment logics governed the hybrid alliance networks.

The evolution of the network structure up to the 2000 snapshot followed an accelerating network model (Dagnino, et al., 2016). One of the characteristics of an accelerating model is that they reach a saturation point where the costs of creating additional alliances exceed its benefits. In our context, the saturation was driven by several factors including the convergence of the most promising product–markets, clarity as to the impact of the 1996 Telecommunication Act and a growing preference for acquisitions that had been limited up to this point (Brennan, 1996; Eugster, Besio and Hawn, 1998; Hsu and Prescott, 2016). While Qualcomm, Lucent, Motorola and Cisco were major players in connected local clusters of alliance partners, Nortel and Ericson had established their own cluster that was indirectly connected to the main cluster in the 2000 snapshot. The global reach of the 2000 network was 64% where 36 of the 99 allying firms were not directly or indirectly connected to the core cluster. It is interesting that 14 of the 36 (39%) alliancing firms that were not connect to the core cluster exited during the 2000 snapshot. By 2004, the network structure became disjointed consistent with structural saturation where a network becomes fragmented or the logic of alliancing change. In our case, alliancing had run its course with respect to addressing the IC event and firms engaged in other adaptive mechanisms such as acquisitions. Further, as our attention and extent of IC timelines demonstrated (Figure 2), firms had shifted their attention to the next generation of IC and the extent of IC had stabilized at 0.37: a state of semi-convergence (Hsu and Prescott, 2016).

Research Question (3): What role does alliancing play in firm survival during IC? Using a survival analysis model, we observed that alliancing improved the likelihood that a firm would

survive the IC event. However, as the extent of IC increased, alliancing negatively affected the chances of firm survival. Finally, as the extent of IC increased when firms increased their alliance partner diversity (more unique alliance partners) it helped their survival chances.

Of our 419 firms, 168 or 40% did not survive the study period. Equipment firms were 63% of the exits while networking firms were 37%. Of the 106 equipment firm exits, 72% were acquisitions, 13% bankruptcy, 6% mergers, 5% bankruptcy then acquired, 3% spinoffs and 1 % restructuring. Of the networking firm exits (62 in total), 74% were acquisitions, 13% bankruptcy, 10% merger and 3% restructuring. We also observed that 26% of the firms that had alliances exited.

In an exploratory survival analysis, we included alliance experience, network measures and a set of firm-level controls. Alliance data obtained from the SDC Platinum database was used to create a firm-level 'alliance experience' variable defined as the cumulative number of alliances up to a given year (Anand and Khanna, 2000). This was the same data used for creating the network snapshots. Alliance network characteristics (centrality, structural holes (hierarchy and constraint)) was obtained using UCINET as part of creating the alliance network snapshots. We operationalized alliance portfolio diversity as the number of unique partners with which a given firm had at least one alliance (Jiang, Tan and Thursby, 2010). Diversity of partners could help survival since it exposes the firm to unique information and resources. We operationalized extent of convergence using cross-industry product market diversification discussed earlier.

Based on the alliance literature, we collected a set of control variable from Compustat. We controlled for firm age and size operationalized as their natural logarithm of revenue. Unabsorbed and financial slack was the natural logarithm of current assets and cash/short term assets

respectively. Prior performance was return of assets for each year while prior acquisition experience was the cumulative number of acquisitions made by a firm up to a given year, (Haleblian and Finkelstein, 1999), and acquisition expense was the log of yearly acquisition expenditures. R&D intensity was the ratio of R&D expense to sales (Cohen and Levinthal, 1989) and capital expenditure operationalized as its natural logarithm. The acquisition, R&D and capital expenditure variables are alternative adaptive mechanisms to alliancing.

We used event history modelling to determine the effect of firm and industry-level variables on firm survival. Since the data did not conform to any specific distributional assumption, we used the semiparametric Cox model with a proportional hazards assumption. The data met the assumptions of no multicollinearity and linearity.

Several interesting observations emerged from the analyses (Table 2). A negative sign indicates a higher likelihood of survival. For the controls, younger firms were more likely to exit consistent with the liability of newness concept. Across all models the alternative adaptive mechanisms, capital expenditures and acquisition expense hurt firm survival while R&D intensity help survival. As the extent of IC increased, the likelihood of survival decreased in all models.

Alliance experience (all models) increased the likelihood of survival but alliance portfolio diversity decreased it in the full model (model 6). This suggests that as firms make more alliances they are more likely to survive due to the benefits of alliance experience. Centrality had a marginally negative effect on firm survival (model 3) but no significant effect in the full model. Network constrain had a marginally negative effect on firm survival (models 5 and 6) implying that a lower degree of access to alternative ties in a firm's alliance network threatens survival.

Finally, the interaction of alliance portfolio diversity and extent of IC enhanced the likelihood of survival (model 6). This implies that as IC increases partner diversity help the likelihood of surviving the IC event. This result underlines the importance of alliancing activity during structure loosening events in two ways. First, it shows that alliancing is an important mechanism to make sense of as well as adapt to an IC structure-loosening event (Madhavan, et al., 1998). Second, it shows that firms can decrease the threat to survival as IC increases by using alliances to enter new product-markets as part of an inter-industry diversification strategy that facilitates adaptation to the structure-loosening event.

The overall set of observations suggests that while alliancing is a positive adaptive mechanism during IC, partner selection is important for enhancing survival. The exploratory analysis also suggests that surviving an IC event involves a complex set of factors that warrants additional attention.

Conclusion and Further Research Directions

Our objectives were to explore the evolution of an alliance network structure during the IC event between the telecommunications equipment and computer networking industries and the role of alliancing in firm survival. Thus, the boundary conditions of our study may appear restrictive in terms of generalizing our observations. However, we contend that industry convergence events have an increasingly impact on many high growth industries where alliancing is a common and key adaptive mechanism for addressing the uncertainties and survival hazards of IC. While IC in the autonomous driving, smart phone, wearable technology and internet streaming industries receive considerable attention, we found that nearly half of the S&P 500 firms compete in industries affected by IC (available from the authors) making IC an important context. Thus, a

contribution of our study was demonstrating that when studying network structure evolution in the IC context, linking EST, the network in transition perspective, and network structure types enabled us to make several observations that assist future theory development.

Further Research Directions

Rosenkopf and Schilling's, (2007) typology of network structures was a useful approach for observing the evolution of the alliance network. Applying their typology, future research examining the evolution of alliance network structures should examine not only across types evolutionary processes (disjointed, hybrid, spiderweb) but also within a type. While we exercised judgement combined with qualitative and quantitative evidence to identify the types of network structure across our five snapshots, measurement approaches such as fuzzy set theory (Fiss, 2007) would provide a more fine-grained approach to study network structure evolution. This would help in further developing a theory of network structure types.

The network in transition perspective (Madhavan, et al, 1998) benefits from drawing on EST by further delineating how exogenous structure-loosening and structure-reinforcing events impact and co-evolve with behaviors, features and other events in an alliance network. Firms are not pawns to events and alliance network structures but can influence them to their advantage. As Madhavan and Prescott (2017) note, a firm's alliance network is an expression of its strategy and desire to establish an advantageous position in its network. In other words, while a firm's network position exhibits characteristics of network endogeneity and inertia, firms exhibit agency as shown when peripheral firms moved to the center. There are perils to moving to the center of an alliance network. We observed that 50% of the peripheral firms that became central exited. Currently, we do not have theory that predicts the types of competitive dynamics firms should use to enhance

their likelihood of survival and thus we encourage additional research using survival as a dependent variable in alliance research. Advances in co-evolutionary theory applied to alliance network evolution (Dagnino, et al., 2016) should include survival as a core outcome variable because when events stimulate network evolution, firm survival is at risk. In our sample firms, 40% of the firms exited which is evidence for the importance of understanding the determinants of survival as networks evolve.

We observed that the hybrid network snapshots exhibited characteristics of attachment logics and eventually a saturation effect (Dagnino's, et al, 2016) as the IC event winded down. In the hybrid networks (1992, 1996 and 2000) we observed that most of the firms in the network were either in direct or indirect contact. In other words, firms in the alliance network has wide reach in their efforts to gain access to information and resources in the network. It would be useful to identify the types of information and resources accessible to the alliancing firms that help their survival. In addition to reach, Gulati, Lavie and Madhavan (2011) proposed richness and receptivity as mechanisms that jointly explain how network resources contribute to organizational performance. Richness is the potential value of the resources available to firms through its ties. Receptivity denotes the extent to which firms can channel network resources across interorganizational boundaries. Research examining all three mechanisms would provide valuable insights as to their individual and joint impact on attachment logics, firm outcomes and saturation effects.

Our findings are subject to generalization limitations that offer future research directions. Our context involved a substitution form of IC. We conjecture that the number and role of alliancing in a complimentary form of IC involve additional complexities especially when there are multiple converging industries. For example, the convergence between biotechnology,

information technology and nanotechnology is creating multiple product-markets such as bioelectronics, nanosensors, bioinformatics and biochips. Firms must make choices regarding which product-markets in which to compete, how alliancing and partner selection helps them gain access to the resources and capabilities necessary to competing in such a diverse and complex setting. Thus, we predict that network endogeneity (Gulati and Gargiulo, 1999; Rosenkopf and Schilling, 2007) and attachment logics (Dagnino, et al., 2016) will have a weaker effect on the evolution of the alliance network leading to less stability in the evolution of the network as well as a high level of firm failure.

A second limit to generalization of our findings involves the pace of IC (Lee, 2016). We conjecture that the relationship between the pace of IC and the role of alliancing in firm survival takes the form of an inverted-U. If industries converge quickly, the "wait-and-see" approach of alliancing does not provide sufficient time for firms to internalize the resources and capabilities necessary for survival. On the other hand, if the pace is slow, firms have sufficient time to develop capabilities internally and thus survive IC. Thus, while alliance will be important, it has a diminished impact relative internal development. This scenario is a plausible prediction for the case of the major automobile manufactures facing complimentary IC in autonomous vehicles. We think that a moderate pace of IC (10 – 20 years) provides ample opportunity for firms to adopt a "wait-and-see" alliancing approach while studying how the evolution of the alliance network affects survival.

Finally, we think that studying the role of events in network structure evolution is not only interesting to network scholars because of their capability to affect the fate of firms but also important because they have multi-level effects on behavior, features and other events (Morgeson, et al., 2015) for which there are many gaps in our knowledge base. In this respect, we hope that

our set of inductively driven observations will lead to additional theory development as to the drivers, mediators, moderators and performance outcomes of network structure evolution. This would complement the large body of network literature that focuses on the ego-level of analysis allowing rich multi-level theorizing.

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Table 1: Type of Network Structure and Features of the Alliance Network Snapshots

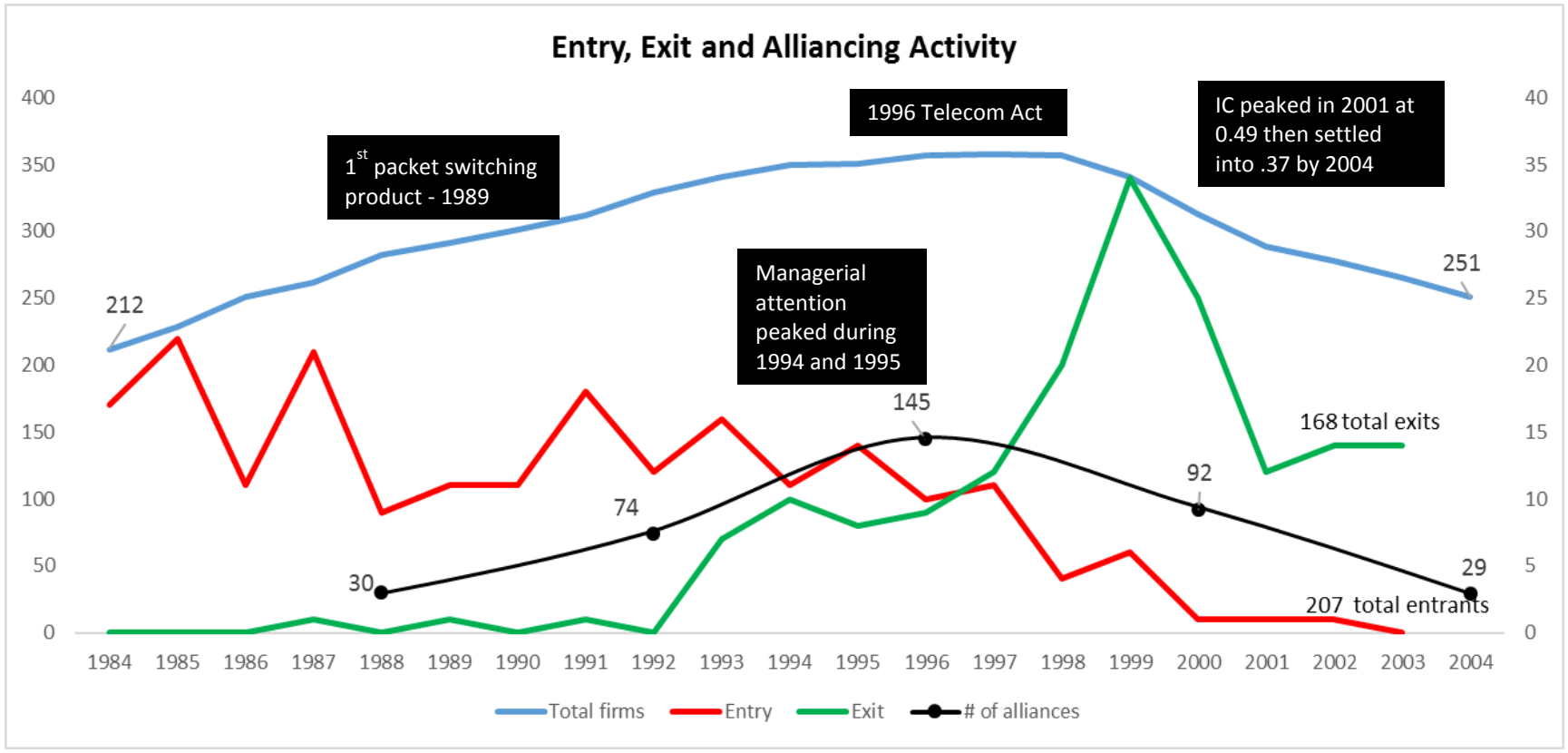
Snapshot/ Features	1988	1992	1996	2000	2004
Snapshot distinguishing characteristic	Pre-IC event	1st packet switching product in 1989	1996 Telecommunication Act	Internet Bubble	End of IC event and beginning of new IC video event
Type of Network Structure	Disjointed	Hybrid	Hybrid	Hybrid	Disjointed
Network Centralization	.005	.020	.033	.014	.007
Total # of firms in alliance network	282	329	357	313	251
Total # of alliances	30	74	145	92	29
# firms with at least 1 alliance	46	70	137	99	41
# of isolates	236	259	220	214	210
Alliance participation rate (e.g., 46/282=16%)	16%	21%	38%	32%	16%
Total # of firm exits	1	2	34	91	40
# of allying firm exits % allying exits	0 0%	0 0%	15 44%	28 31%	0 0%
Extent of IC	0.15	0.20	0.30	0.39	0.37

Table 2: Event history modelling (Survival analysis) results: Semiparametric Cox Model

Variables	**Model 1 (controls)**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
Size	-3.38 (2.31)	-3.32 (2.27)	-3.44(2.21)	-3.38 (2.21)	-3.25 (2.27)	-3.17 (2.29)
Age	-0.05*** (0.01)	-0.05*** (0.01)	-0.05*** (0.01)	-0.05*** (0.01)	-0.04***(0.01)	-0.05*** (0.01)
Unabsorbed slack	-1.76^{+} (0.96)	-1.79* (0.95)	-1.83* (0.96)	-1.61^{+} (0.85)	-1.85*(0.92)	-1.92* (0.96)
Financial slack	1.76^{+} (1.03)	1.75^{+} (1.02)	1.81^{+} (1.01)	1.17^{+} (1.03)	1.81^{+} (1.06)	1.74 (1.08)
Year wise control (dummy)	0.54* (0.24)	0.54* (0.24)	0.51* (0.24)	0.49* (0.24)	0.46^{+} (0.24)	0.46* (0.24)
Wireless focus	0.26 (0.24)	0.27 (0.24)	0.27 (0.24)	0.27 (0.24)	0.29 (0.24)	0.23 (0.24)
Prior performance	1.41(2.52)	1.39 (2.53)	1.56 (2.61)	1.57 (2.65)	1.27 (2.29)	1.14 (2.01)
Capital expenditure	2.19*(0.87)	2.17* (0.89)	2.21* (0.94)	2.21* (0.94)	2.14* (0.89)	2.22* (0.95)
Prior acquisition experience	0.22 (0.24)	0.32(0.25)	0.31 (0.25)	0.31 (0.25)	0.32(0.24)	0.11 (0.26)
Acquisition expense	1.00* (0.43)	1.00*(0.42)	1.05* (0.41)	1.03* (0.41)	0.94^{+} (0.40)	0.90* (0.46)
R&D intensity	-1.01***(0.27)	-1.00*** (0.27)	-1.07***(0.27)	-1.05*** (0.27)	-1.01*** (0.32)	-0.84**(0.27)
Alliance portfolio diversity	-0.06 (0.05)	0.19(0.13)	0.16(0.12)	0.16(0.12)	0.17(0.13)	0.37**(0.15)
Extent of IC	4.39***(0.75)	4.41*** (0.76)	4.46***(0.76)	4.47*** (0.76)	4.53***(0.76)	5.27***(0.84)
Alliance experience		-0.25*(0.12)	-0.22*(0.11)	-0.28*(0.11)	-0.24*(0.12)	-0.27*(0.12)
Alliance network centrality			8.26^{+} (4.66)	7.46 (5.78)	2.57 (6.81)	2.68 (6.38)
Network hierarchy (structural holes)				0.44 (0.80)	-1.75 (1.46)	-2.02 (1.49)
Network constraint (structural holes)					2.44^{+} (1.38)	2.72^{+} (1.43)
Alliance portfolio diversity x Extent of IC						-0.56* (0.23)
Log likelihood	-734.71	-715.43	-714.45	-717.64	-716.47	-713.87
$\chi^2(19)$	218.54***	256.89***	258.8***	252.47***	254.8***	259.99***

The analysis is based on 4214 firm-year observations covering 231 firms of which 110 did not survive. The remaining 188 firms were excluded from analysis due to unavailability of data on the extent of convergence measure. Estimated robust standard errors appear in parentheses. +p<0.10; *p<0.05; **p<0.01; ***p<.001; b- The values in brackets signify the robust standard errors. Positive effect sizes indicate a lower likelihood of survival while negative effect sizes indicate a higher likelihood of survival.

Figure 1: Entry, Exit and Alliancing Activity



Alliance participation rate	16%	21%	38%	32%	16%

- 13% CAGR in sales between 1986 – 2006
- Uncertainty - 12.8 % (10.2%) Industry Sales Volatility
- Substitution Effect – in 1991 number of firms that operated in data market surpassed voice market (expanded growth between 1994 and 2001)

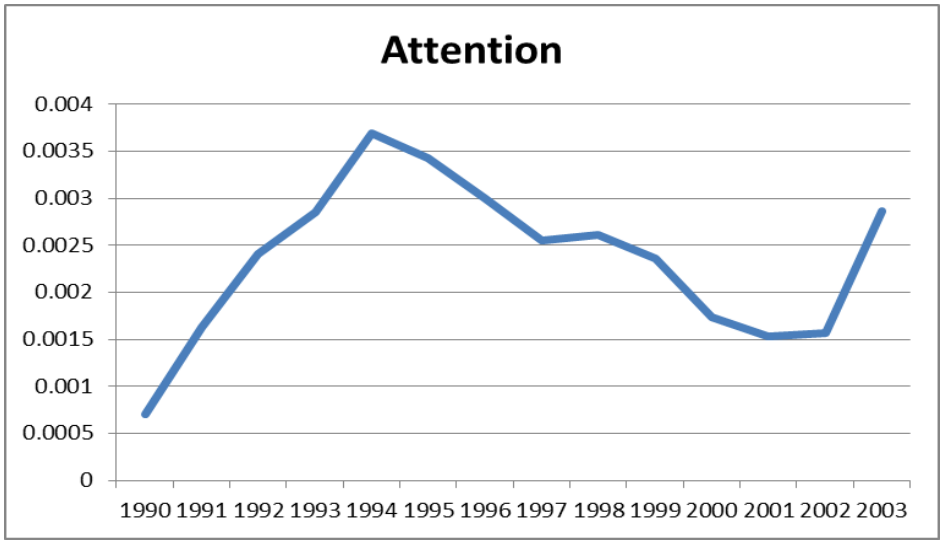
- 419 total firms between 1984 – 2004
- Net entry of 39 firms
- 40% firms exited 168/419 – 72% via acquisition
- 63% exits – Equipment firms
- 26% of firms that exited had alliances

Figure 2: Pre-Event - "Disjointed" Alliance Network: 1988

<u>Attention</u> – content analysis of convergence-related words in 'Letter to shareholders'

- **<u>Peaked</u> in 1994 – 1995**
- **<u>1996</u> – when exits and entries crossed (exits exceeded entrant from then on)**

Attention is calculated as a three-year decaying stock variable to capture attention during a window of time (Eggers and Kaplan, 2009).



Extent of IC – ratio measure – where r_{ij} is the number of firms operating concurrently in product market pair *i* and *j*. (37 data, 28 voice product lines)

$$\textbf{Extent of IC} = \frac{\sum_{j=1}^{37}(\sum_{i=1}^{28} r_{ij})}{1036}$$

- **<u>Peaked</u> in 2001 at 0.49**

Li and Greenwood (2004)

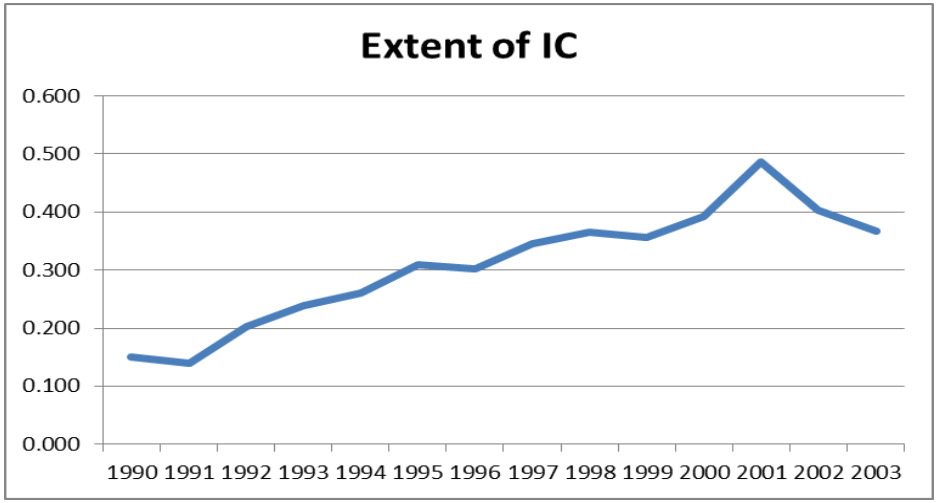
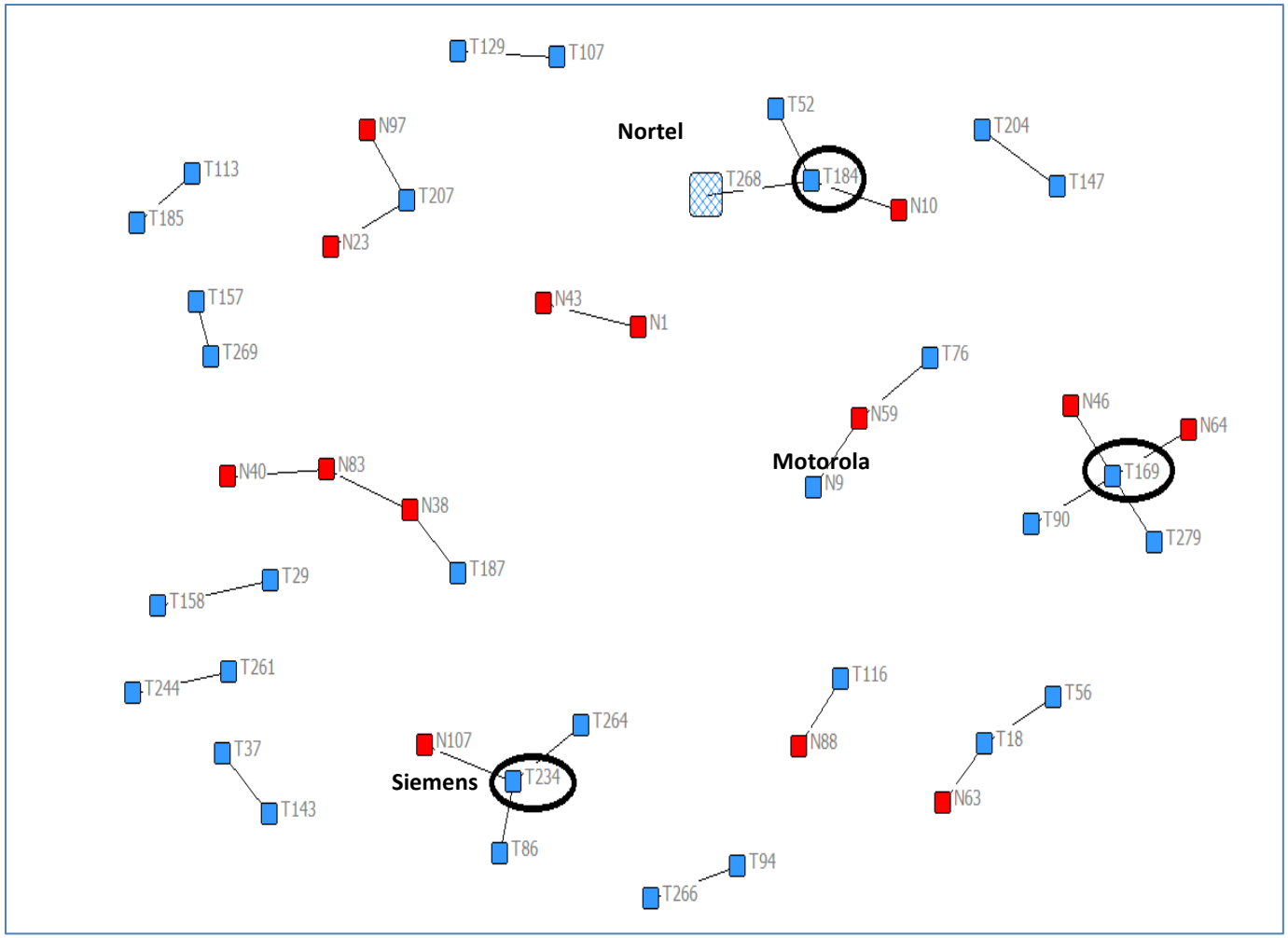


Figure 3: Pre-Event - “Disjointed” Alliance Network: 1988

Total firms in alliance network	282
Number of firms with alliances	46
Isolates	236
Participation rate	16%
# of alliances (repeats)	30(1)
Total Exits	1
Allying firm exits	0
% Allying exits	0%
Centralization	.005

Equipment firms – Blue
Network firms – Red
Surviving firms – Small boxes
Exiting firms – Large

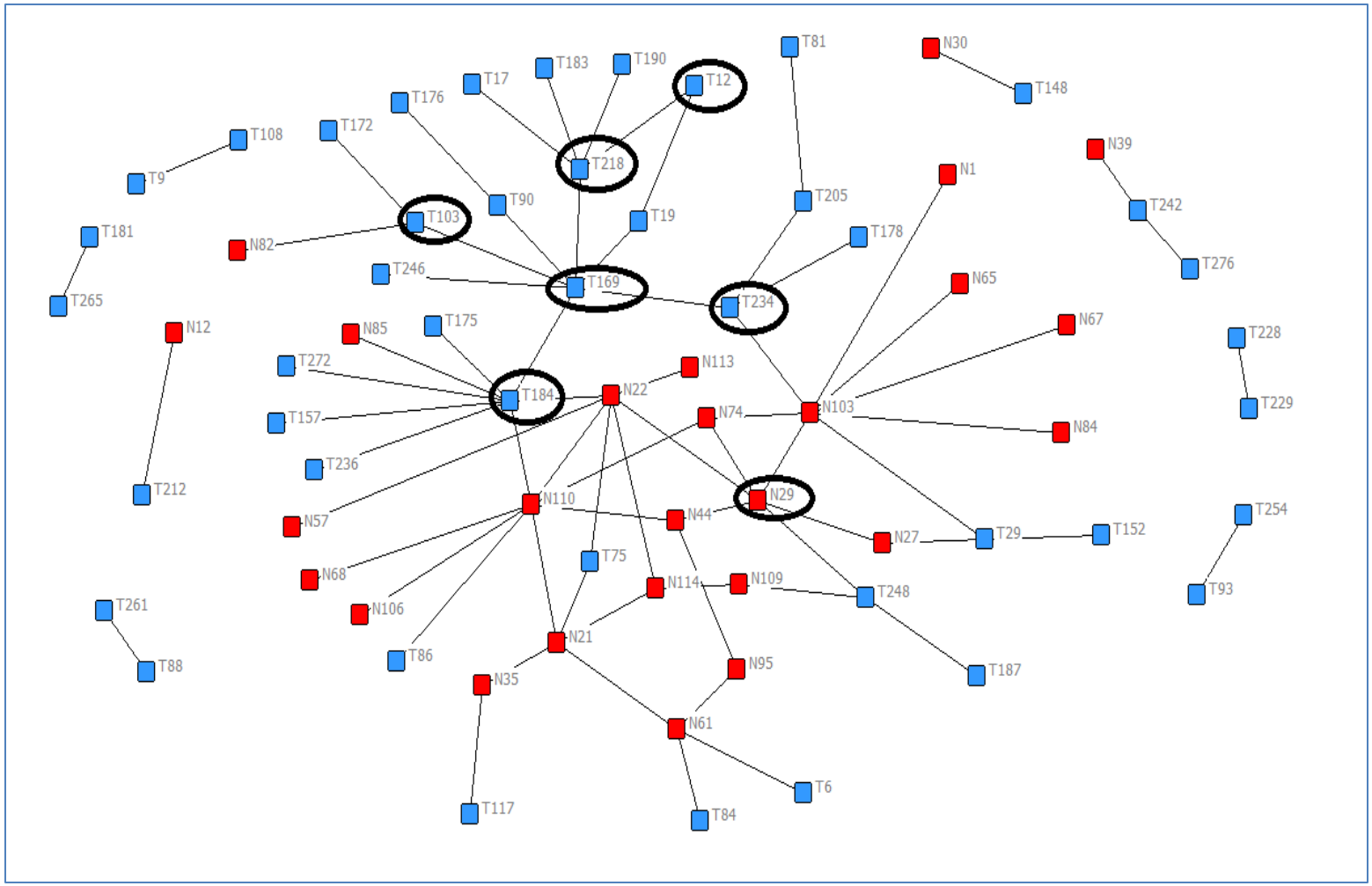


Wave 1 → Firms central by ‘92 and remain central through 2000

Figure 4: “Hybrid” Alliance Network: 1992

Total firms in alliance network	329
Number of firms with alliances	70
Isolates	259
Participation rate	21%
# of alliances (repeats)	74(2)
Total Exits	2
Allying firm exits	0
% Allying exits	0%
Centralization	.020

Equipment firms – Blue
Network firms – Red
Surviving firms – Small boxes
Exiting firms – Large boxes



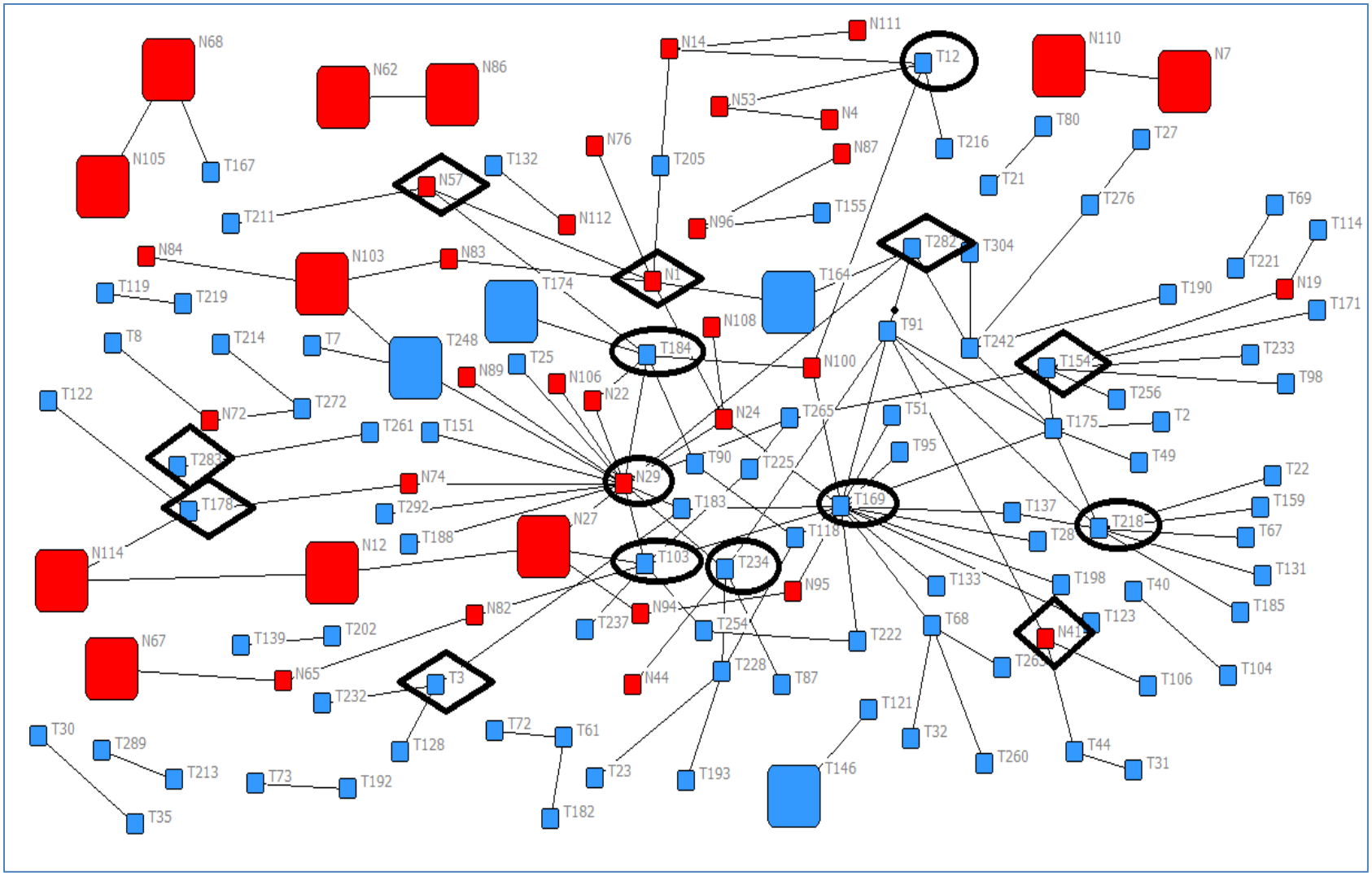
Wave 1

T169 – Motorola
T184 – Nortel
T234 – Siemens
N29 – Cisco
T218 – Qualcomm
T103 – Ericson
T12 - Alcatel

Figure 5: “Hybrid” Alliance Network: 1996

Total firms in alliance network	357
Number of firms with alliances	137
Isolates	220
Participation rate	38%
# of alliances (repeats)	145(2)
Total Exits	34
Allying firm exits	15
% Allying exits	44%
Centralization	.033

Equipment firms – Blue
Network firms – Red
Surviving firms – Small boxes
Exiting firms – Large boxes



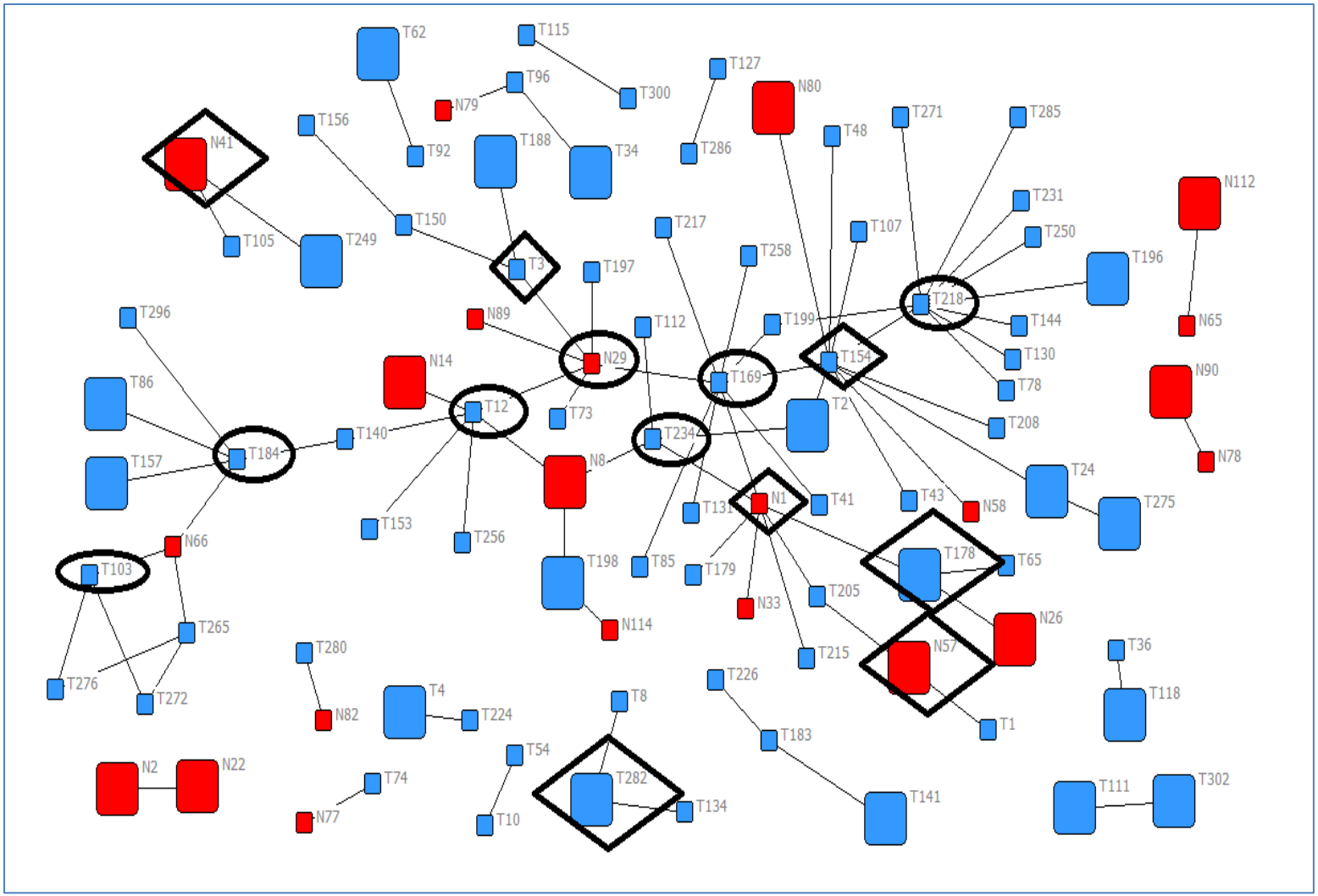
Wave 1 Wave 2

T154 – Lucent
N1 – 3Com
T282 – US Robotics
T3 – ADC Telecommunications
T178 – Newbridge Networks
T183 – Nokia
N41 – Dialogic
N57 – FORE Systems

Figure 6: “Hybrid” Alliance Network: 2000

Total firms in alliance network	313
Number of firms with alliances	99
Isolates	214
Participation rate	32%
# of alliances (repeats)	92(4)
Total Exits	91
Allying firm exits	28
% Allying exits	31%
Centralization	.014

Equipment firms – Blue
Network firms – Red
Surviving firms – Small boxes
Exiting firms – Large boxes



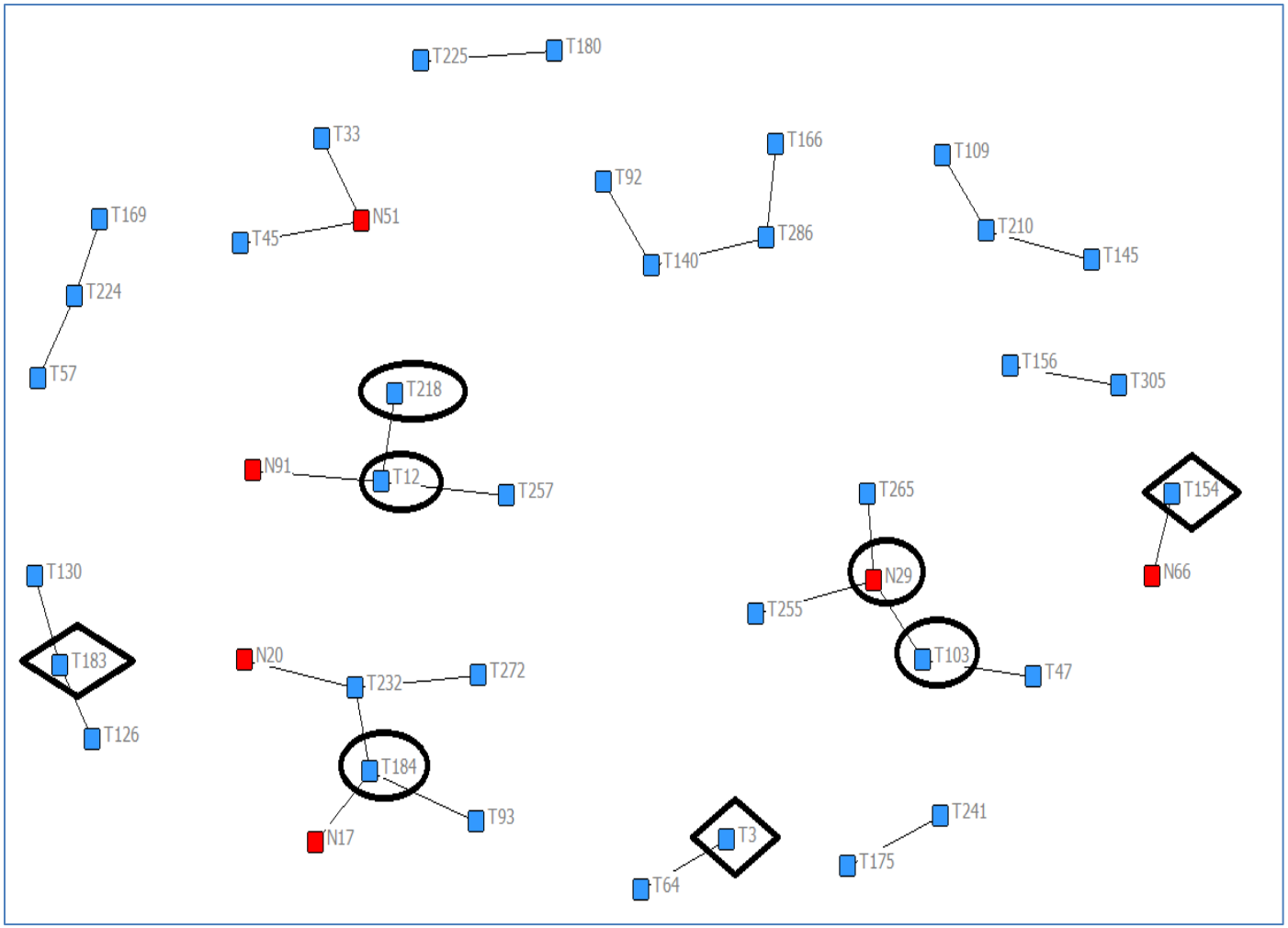
Wave 1 Wave 2

T154 – Lucent
N1 – 3Com
T3 – ADC Telecommunications
T183 – Nokia
T178 – Newbridge Networks
N41 – Dialogic
N57 – FORE Systems
T282 – US Robotics

Figure 7: Post Event "Disjointed" Alliance Network: 2004

Total firms in alliance network	251
Number of firms with alliances	41
Isolates	210
Participation rate	16%
# of alliances (repeats)	29(1)
Total Exits	40
Allying firm exits	0
% Allying exits	0%
Centralization	.007

Equipment firms – Blue
Network firms – Red
Surviving firms – Small boxes
Exiting firms – Large boxes



Wave 1 Wave 2