Incompatible Entry on Small-World Networks

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OUTLINE

○ Motivation and Research Questions
○ Prior Work
○ Contribution
○ Model
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○ Discussion
MOTIVATION

Instant Messaging

- Network effects (benefits): Customers benefit from exchanging messages instantly with others
- AOL first introduced IM service in 1996
- Microsoft, Yahoo, and others entered after AOL established a large installed base
- AOL kept their services incompatible with others
Would AOL monopolize the market?

"The power of the network effect can be seen in technologies like America Online's Instant Messenger. Once teens realized that they could gab after school online, it became a must-have, Mr. Varian said -- and its use exploded, rapidly bringing AOL a near-lock on a market of more than 100 million people that Microsoft is struggling to break into." (New York Times, 2001)

"Instant messaging, such as AOL Instant Messaging, or Microsoft or Yahoo Messaging, has strong literal network effects and without interoperability will likely evolve into a winner-take-all result." (Liebowitz 2002: p. 21)

- FCC imposed some restrictions on AOL
AOL does not seem to be monopolizing the market

- William Rogerson argued: “There is no longer any plausible reason to conclude either that AOL is dominant or that the market is in danger of ‘tipping’ to AOL” (Hu, 2003).

- FCC chairman Michael Powell argued: “The fact that AOL Time Warner’s market share is decreasing in a growing market, combined with the fact that two nontrivial competitors—Microsoft and Yahoo—have established stable and growing market shares, directly contravenes the theory that the market is tipping towards AOL Time Warner” (McCullah and Hu, 2003).

- **FCC lifted its restrictions** on AOL in 2003

- The market is becoming more fragmented as corporate IM offers lucrative opportunities.
RESEARCH QUESTIONS

○ What made the experts confusing?

○ Under what conditions does a new, incompatible technology survive or even win the market?

○ Does installed base always matter?
PRIOR WORK

Controversy over Incompatible Entry

- A (superior) new technology may not gain a footing
  - Farrell and Klemperer (2001)

- Many new, incompatible technologies have been introduced to the market successfully
  - Katz and Shapiro (1992, 1994)
Positive Feedback

The Winner-Take-All Process

Benefits: Installed Base

Adoption

+ +

Winner’s Virtuous cycle

Benefits: Installed Base

Adoption

- -

Loser’s Vicious cycle
Connection to Research on Complex Systems

- A deceptively simple pattern can emerge from a large interactive system
  - e.g.) Slime mold, Bose-Einstein condensation, and the winner-take-all market
- Pattern “can arise as epiphenomena through nonlinear interactions,...” (Parrish and Edelstein-Keshet 1999)
Pattern in Slime Mold

- Under some conditions, the slime-mold cells move toward one another, forming a cluster.

- In this aggregation phase, they produce and emit cAMP into the environment.

- Positive feedback (Nonlinear Interactions)
  - The more cAMP in a cluster, the more slime-mold cells it attracts
  - The more slime-mold cells attracted to the cluster, the more cAMP they drop in the cluster (Resnick 2001: p. 50-52)
Contribution and Limitation of Prior Research

- Highlighted an emergent pattern (the winner-take-all) from nonlinear dynamics by focusing on installed base
- Sidestepped the complexity of network topology
Why is network anatomy so important to characterize?

"Because structure always affects function. For instance, the topology of social networks affects the spread of information and disease, and the topology of the power grid affects the robustness and stability of power transmission." (Strogatz, 2001)
CONTRIBUTION

- Structural complexity:
  - Network topology can act as a brake on the nonlinear dynamics

- Our answer to the debate on incompatible entry:
  - In some network structures, the winner-take-all (tippy) outcomes are possible, whereas in other networks, incompatible technologies can share the market.
Complex Networks

- Complete (or fully-connected) networks
  - Everyone is directly connected to everyone else
  - A typical assumption for prior work

- Sparse networks
  - Random networks (Erdős and Rényi 1959)
  - **Small-world networks**
    - Hubs (Barabasi and Albert 1999; Barabasi, Albert, and Jeong 1999)
    - Social bridges or shortcuts (Granovetter 1973, Watts and Strogatz 1998)
Complete Network
Buddy List: Sparse Network

- In AOL, a typical buddy list consists of about 20 to 50 acquaintances (The Ottawa Citizen, 1999)

- The majority of others in the AOL network is irrelevant
Smallness due to Hub

- WWW
- The Internet
- Airline networks
- Cellular networks
- Sexual-contact networks
- Food web
Smallness due to shortcut

- Social networks
  - E.g.) A flight attendant for Air Canada played a key role in spreading AIDS among homosexuals who were locally isolated in several regions.
- Neural networks
**K-Regular Graph (Lattice)**

- High degree of clustering:
  - Two nodes share common neighbors (e.g., coworker networks)
  - Redundancy (Granovetter, 1973)

- No shortcuts
  - Physical distance constrains interactions among nodes
4-Regular Graph
Random shortcuts

- Often, social contact is not constrained by physical distance.
  - E.g.) Spam mail, Viral marketing, Internet chat room, & Internet auction

- Rewiring $k$-regular graph with probability $\beta$ (Watts and Strogatz 1998).
The Watts Strogatz Model

Regular  Small-world  Random

\( \beta = 0 \)  \text{Increasing randomness}  \rightarrow \beta = 1

No shortcuts  Lots of Shortcuts
Communication Technologies and Shortcuts

No or few shortcuts  E-mail  Lots of shortcuts

Corporate Instant messaging  E-mail  Chat room
MODEL

○ Purchasing Decision
  - Each individual buys a product if....

Reluctance to adopt < Network effects (benefits)
Reluctance Distribution and Adoption

Tech Enthusiasts

$\mu$

$R_i$

Adoption
Basic Model

- Two competing technologies
- Individual $i$'s willingness to adopt $j$ at time $t$

\[ U_{it}^j = R_i + an_{i(t-1)}^j \]

- $R_i$ = Customer $i$'s reluctance to buy $\sim N(\mu, \sigma^2)$
  - One can think that $R_i = r_i - p$ ($r \leq 0$ & $p \geq 0$)

- $n_{i(t-1)}^j$ = The number of adopters among $i$'s acquaintances
  - The number of $i$'s acquaintances
Social Clustering and Local Bias

“In marketing End-Note to the academic market, our company often came across university departments that were defined as ‘All Macintosh’ or ‘All PC.’ Software usage followed the same pattern: You could find a cluster of WordPerfect users in one building at a university and a cluster of Microsoft Word users in another building.” (Rosen 2000: p. 63)
Properties of the Basic Model

- The number of customers \((N)\) does not affect the dynamics
- Dynamics are insensitive to the degree of interaction \(k\)
  - Assumption: \(0 \ll k \ll N\)
- The replacement happens at every time step
  - A change in replacement cycle does affect the long-run behavior
Sequential Entry

○ **Stage one:**
  - Diffusion for the established technology

○ **Stage Two:**
  - Introduction of a new incompatible technology at time $T_{entry}$
  - Competition for customers
Figure 2. Adoption dynamics:
A. Typical simulation run with $\beta = 1$
B. Typical simulation run with $\beta = 0.1$
C. Typical simulation run with $\beta = 0$
Network Topology and Survival Probability

Variation in timing of the new technology introduction
Network Topology and Survival Probability

Variation in incumbent’s installed base
Competition of Market Share by Network Topology

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Variation in incumbent’s installed base

MSD vs. Beta
Tipppy Regime
Measure of Tippiness

- Formally, tippiness $\theta$ is measured as

$\theta = \frac{\sum \left| \pi^\text{Old}_i - \pi^\text{New}_i \right|}{M}$

$\pi^j_i = \text{ith realization of technology } j\text{'s (}j = \text{old, new) market share at the steady state}$

$M = \text{the total number of simulation runs.}$
Cumulative Distribution of MSD:

$\beta = 0$
Extended Model

- Individual $i$'s willingness to adopt OLD at time $t$
  \[ U_{it}^{OLD} = R_i + a_n^{OLD}_{i(t-1)} \]

- Individual $i$'s willingness to adopt NEW at time $t$
  \[ U_{it}^{NEW} = R_i + a_n^{NEW}_{i(t-1)} + c \]

- $c$ represents extra benefits for customers, which stem from the entrant's strategic actions
Entrant's strategic action

Tippy Case: $\beta = 1$
Entrant's strategic action

Tippy Case: $\beta = 0.8$

Extra benefit
Entrant's strategic action

Tippy Case: $\beta = 0.6$
Entrant’s strategic action

Tippy Case: $\beta = 0.4$
Entrant's strategic action

Quasi-tippy Case: $\beta = 0.2$
Entrant's strategic action

Non-Tippy Case: $\beta = 0$
CONCLUSION

Summary

- Our findings shed light on the acrimonious debate in the literature.
  - The survival probability of a new, incompatible technology depends on the tippiness of a system, which is largely a function of network topology.

- Research on network topology is important because structure affects function in complex systems (Strogatz 2001, Buchanan 2002).

- When its role is ignored, even experts would be confused (e.g., the IM market).
Strategic Implications for Entrants

- Sparse networks with few or no shortcuts
  - An entrant can attempt to create a niche or even win the market by offering an incompatible technology
  - Offering extra stand-alone benefit would be effective

- Sparse networks with substantial shortcuts
  - Incompatible entry is very hard like a typical case in fully-connected networks