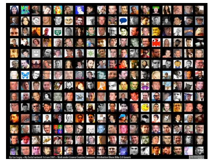

Social and Technological Network Analysis

Lecture 7: Information Cascades

Dr. Cecilia Mascolo

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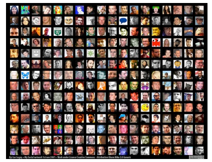
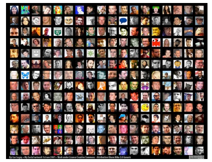
In This Lecture



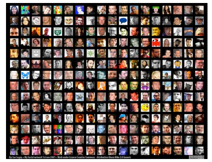
- In this lecture we introduce the concept of "cascades" of information in networks and show examples and trade-offs for these to happen.



Decision Making and Behaviour Influence

- How is new behaviour adopted?
- How does technology usage spread?
- People influence on ideas?

- The social network plays an important role in the decision making process
  - We study how.



Early studies on Influence

- Ryan and Gross (1943) on adoption of hybrid corn in Iowa
  - Farmers learned of the corn from salesmen but were convinced on adoption by experience of neighbours in the community.
- Coleman, Katz and Menzel (1966) on adoption of tetracycline in US
  - Map of social connections among doctors.
  - Early adopter had higher socio-economical status and travelled more widely (also in corn case).
  - Decision on adoption was made in the context of the social structure (observing neighbours, friends and colleagues).

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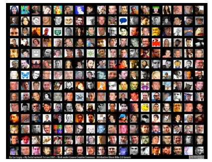
Model of Diffusion



- Nodes v and w and behaviours A and B
  - If both v and w adopt A, they each get payoff a>0
  - If both adopt B, they each get a payoff b>0
  - If they adopt opposite behaviour they both get a payoff of 0

		w: A	w: B
v	A	a, a	$0, 0$
	B	$0, 0$	b, b

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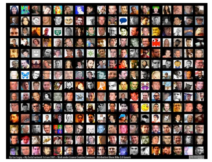


Network Implications

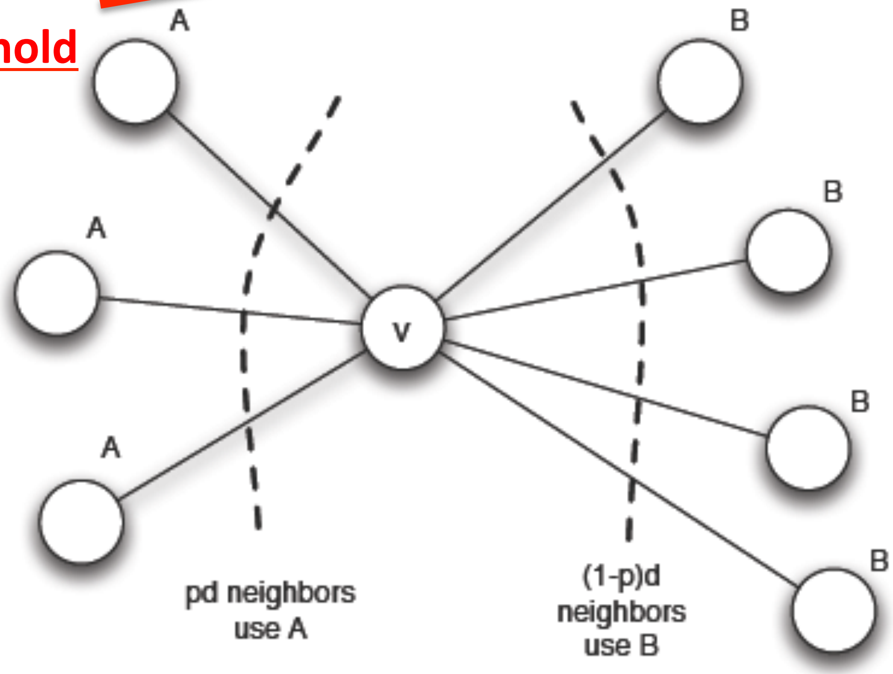
- p fraction of neighbours choose A
- (1-p) choose B
- d neighbours then: pd choose A and(1-p)d choose B

A better choice if :

$$pda \geq (1-p)db$$

$$p \geq \frac{b}{a+b}$$

threshold



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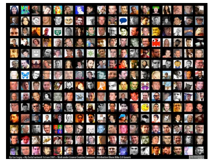
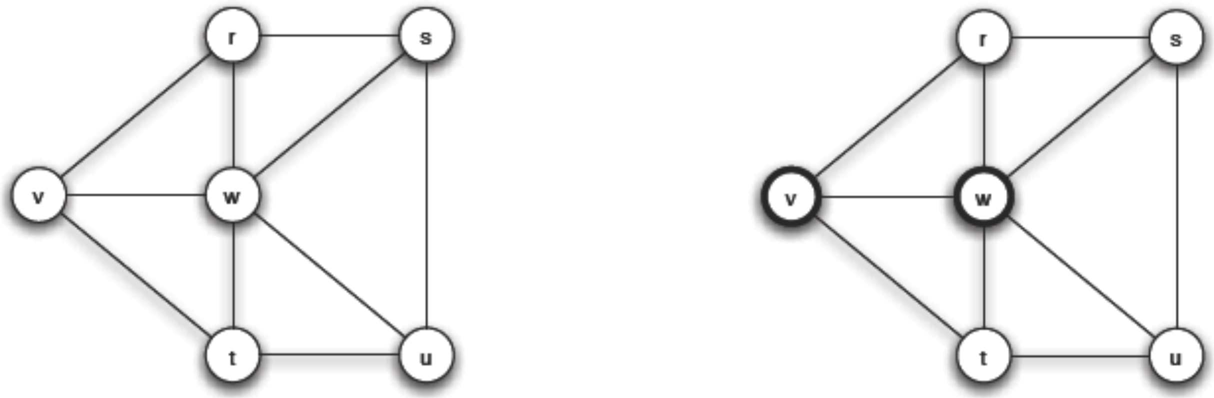


Larger Horizon

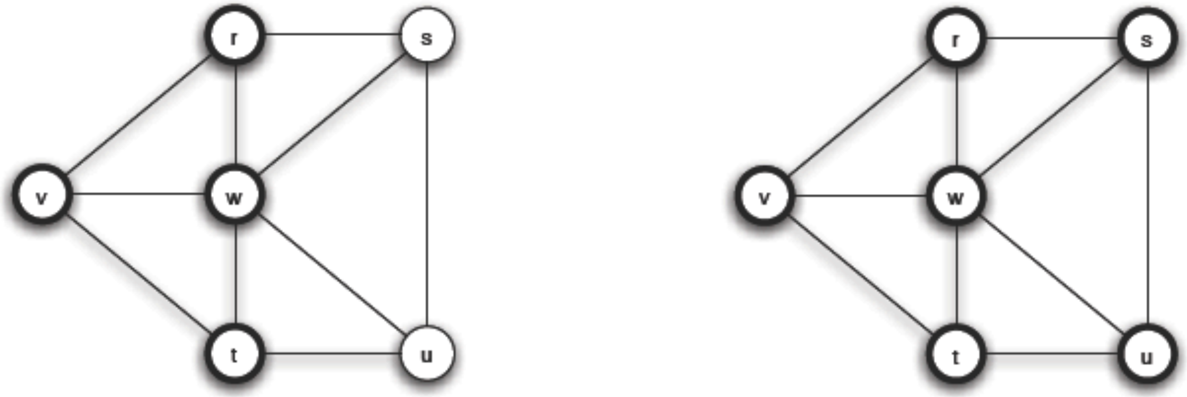
- A is new behaviour

- a=3, b=2
- b/a+b=2/5



(a) *The underlying network*

(b) *Two nodes are the initial adopters*



(c) *After one step, two more nodes have adopted*

(d) *After a second step, everyone has adopted*

Light circles=B
Dark circles=A

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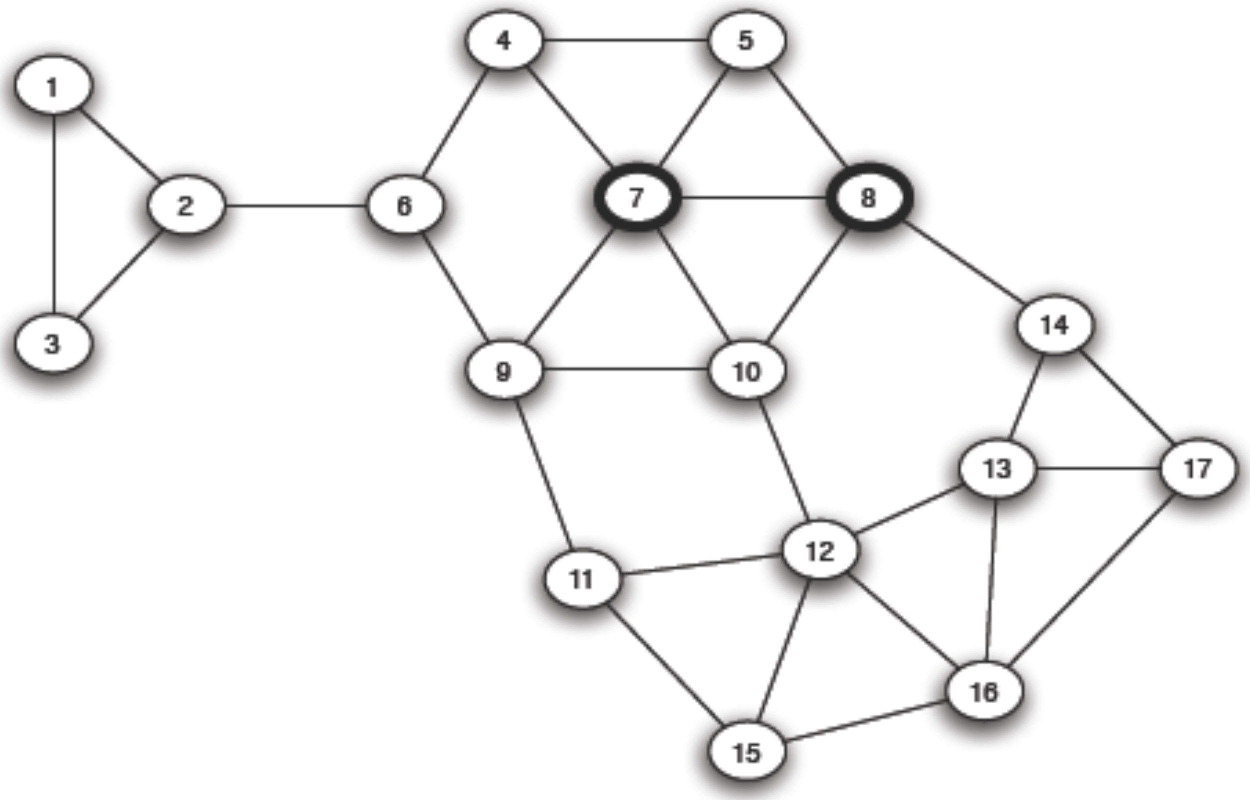
Example explained

- 1st step: only v and w adopt A
- 2nd step: nodes r and t switch to A. 2/3 > 2/5 of neighbours choose A. u does not switch: 1/3<2/5 of neighbours chose A
- 3rd step: s and u switch to A

Chain Reactions



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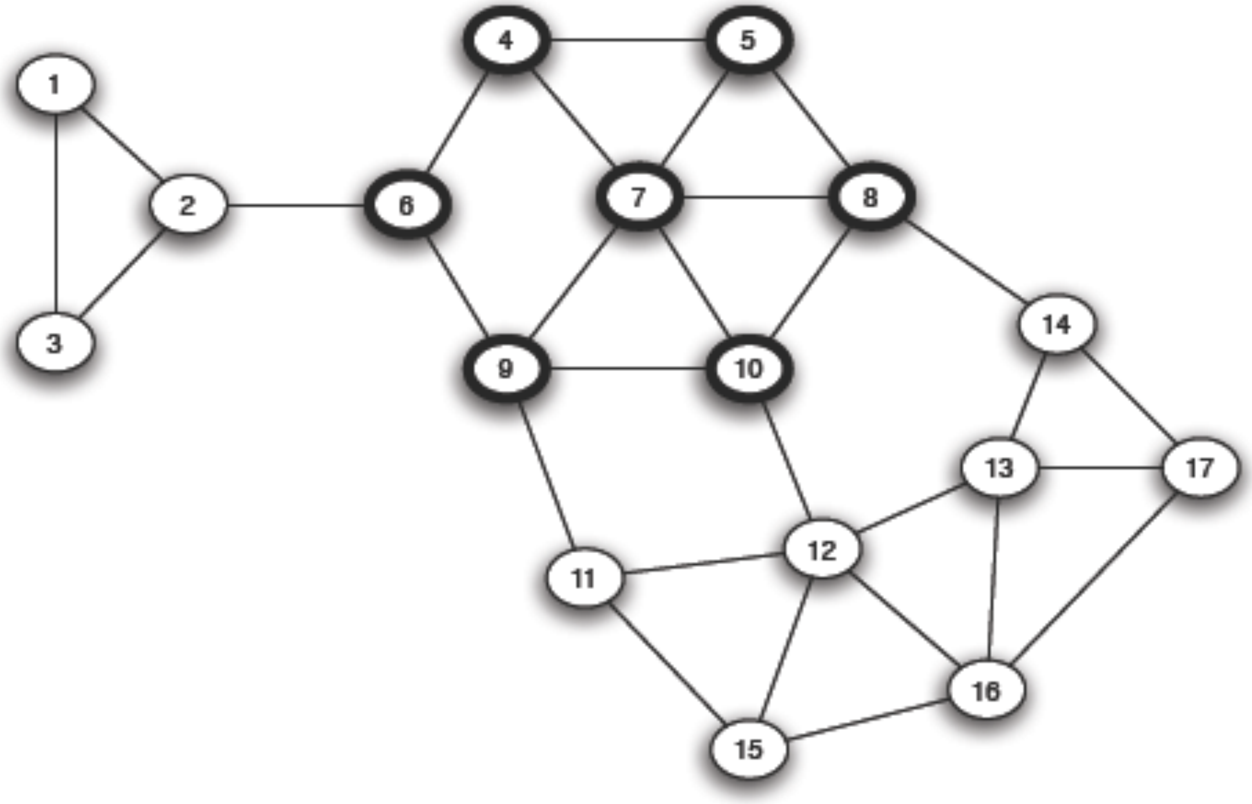
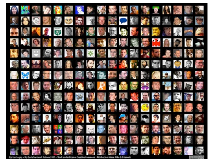
Cascade Stops!





Cascades

- In some cases initial adoption by some nodes generate a **complete cascade** [for a specific threshold]

- Note that changing the threshold would change the behaviour in previous example
  - Threshold of 1/3 would generate a complete cascade

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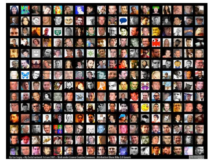
Viral Marketing



- How to penetrate new areas of the network
- Dissemination does not depend only on the network structure but also on this threshold!
  - Change the payoff! I.e., change the quality of the product [make a product slightly more attractive].
- When threshold cannot be changed
  - Convince key network nodes to switch (e.g nodes 12/13 good, but nodes 11 and 14 bad).

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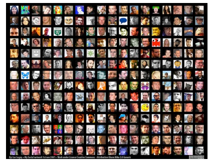
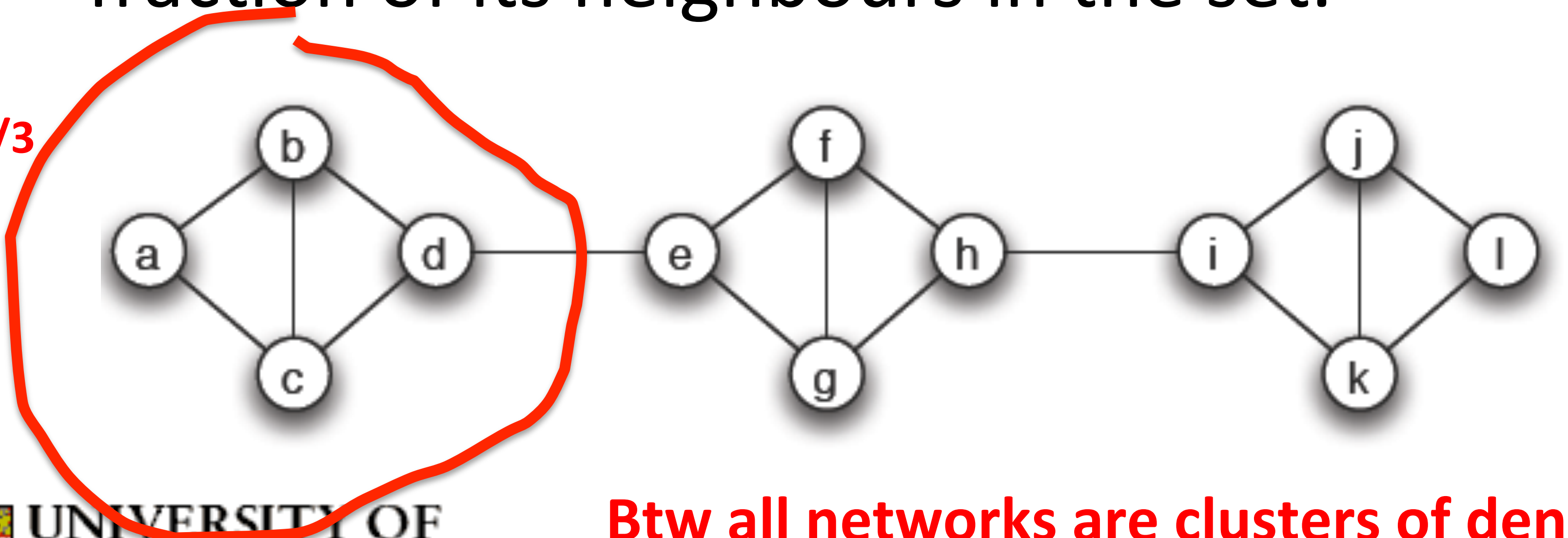
What Makes Cascades Stop?



- Tightly knit communities sometimes cannot be penetrated.
- A cluster of density p is a set of nodes such that each node in the set has at least a p fraction of its neighbours in the set.

2/3



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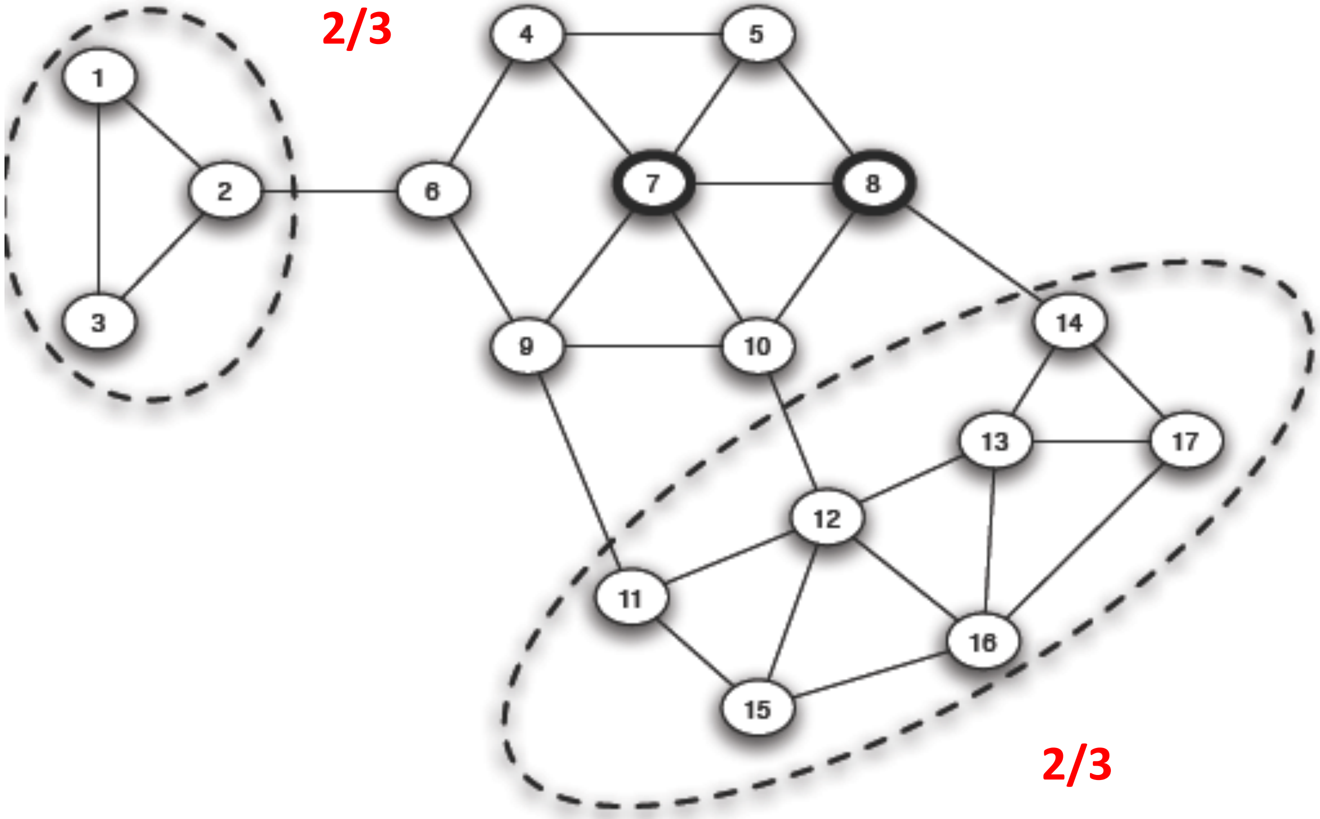
Btw all networks are clusters of density 1

Clusters as Obstacles to Cascades



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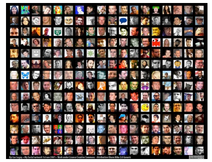

Clusters and Cascades Relationship

- Set of initial adopters of A (S), threshold q

1. If the remaining network contains a cluster of density greater than 1-q then set S will not cause a complete cascade.
2. Whenever set S does not cause a complete cascade with threshold q the remaining network must contain cluster of density greater than 1-q

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Proof of Part 1

- Consider S and q in a network.
- Let's assume the network contains a cluster of density >1-q
- We need to prove*:*
  - *No node in the cluster will ever adopt A.*

- Let's assume that node v inside the cluster is the first to adopt A (at time t).
- At time t-1 no neighbour of v in the cluster adopted A.
  - Neighbours must be outside the cluster.

Proof of Part 1 Continued

- Since cluster has density >1-q, more than 1-q neighbours of v are inside and <q neighbours are outside.
- The threshold to switch is q and number of v's neigbours who have switched before time t is <q so it is impossible that v switched.

- [we do not prove part 2 here]

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Cascade Capacity of Networks

- **Cascade Capacity** of a network is the largest value of the threshold q for which some finite set of early adopters can cause a complete cascade

- In the following case cascade capacity is ½
  - Even if the network is infinite

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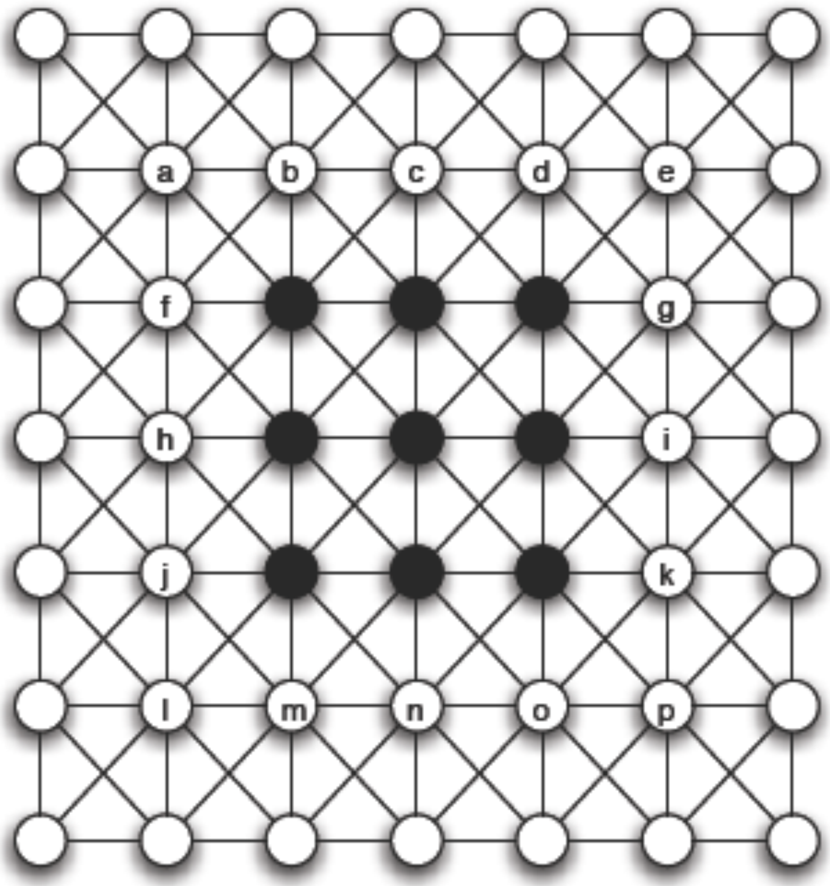
For q<=1/2 complete cascade

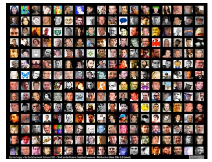
Cascade Capacity on a Grid

- If q <=3/8 there is a complete cascade
- If q is smaller (eg 2/8) cascade spreads even faster.
- Cascade Capacity is 3/8

- A network with a **large capacity** is one where cascades happen easily.



How large can Cascade Capacity be?



- Can it be higher than ½?
  - This would mean for instance that an inferior innovation can displace a superior one even when the inferior innovation starts with few initial adopters.
- No: we will show that no network has a capacity higher than ½.

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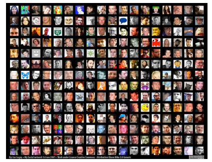
No Network has Capacity >1/2



- We need to show that when q>1/2 the spreading process cannot reach all nodes.
- *Interface set*: set of edges between A and B nodes.
- We will show that at each step the size of the interface set decreases.
- Initial interface set: finite I_0 from initial adopter set S.
- If interface set decreases, the process runs only for I_0 steps and terminates with only a finite number of nodes adopting A.

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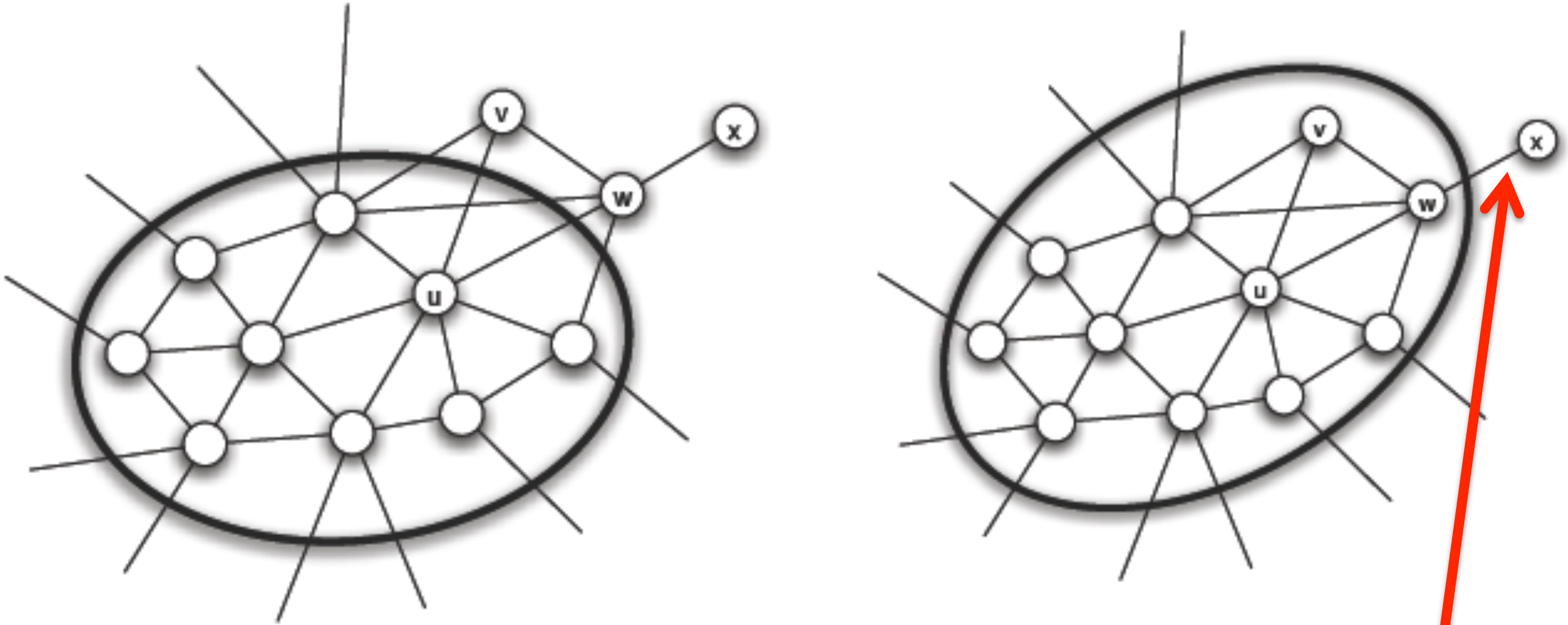
Example of interface set change



(a) *Before v and w adopt A*   (b) *After v and w adopt A*

Edge xw is now an interface edge

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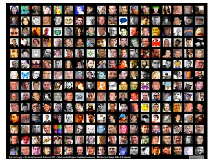
Proof



- Let’s consider node w switching at time t.
- At time t-1 w has“a” edges to nodes adopting A and “b” edges to nodes adopting B.
- w now switches to A so the “b” edges are now interface edges and “a” edges are not any longer.
- Since q>1/2 and w switches, it must be that a>b.
- Hence the interface set decreases at each step.

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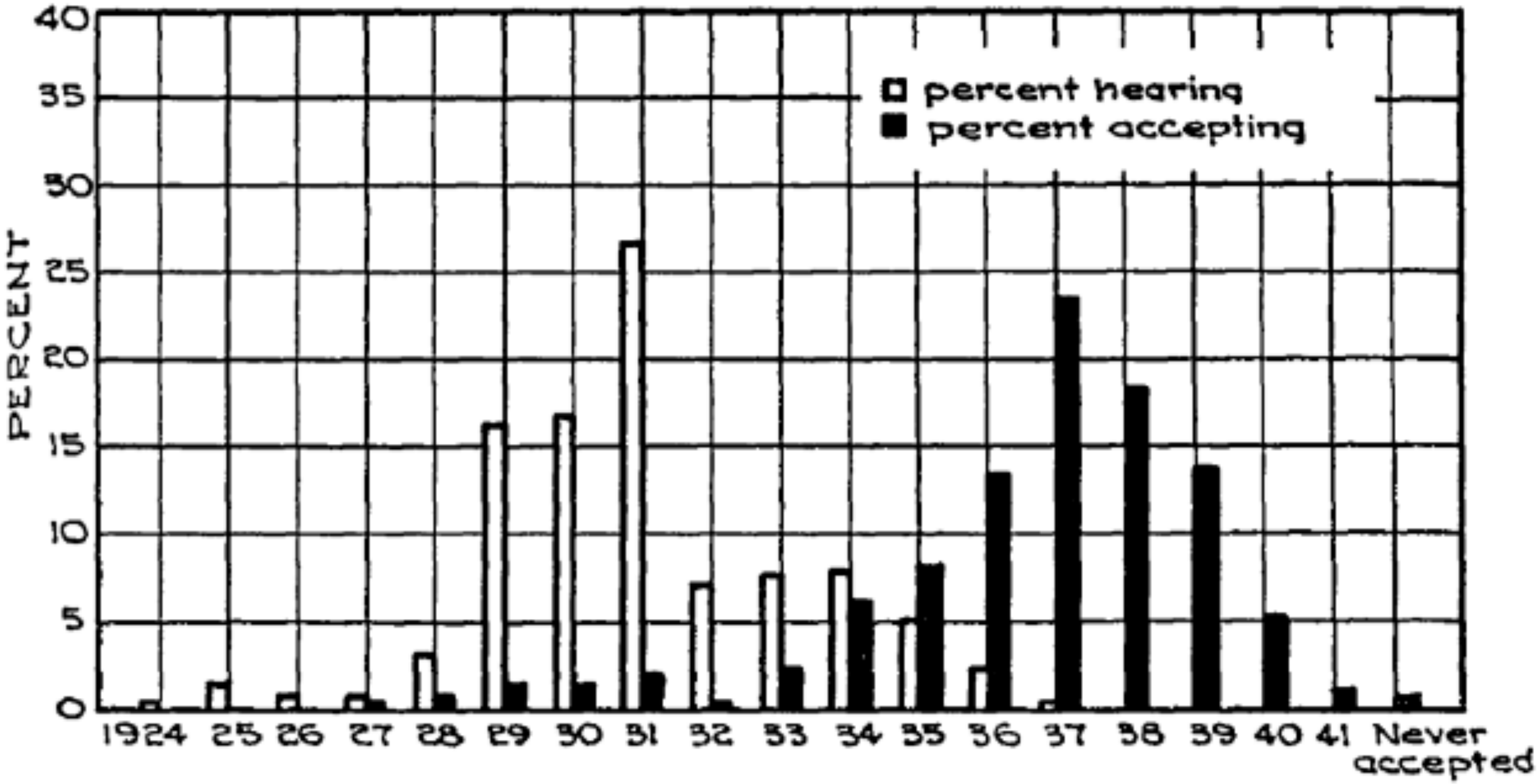
Learning versus Adopting



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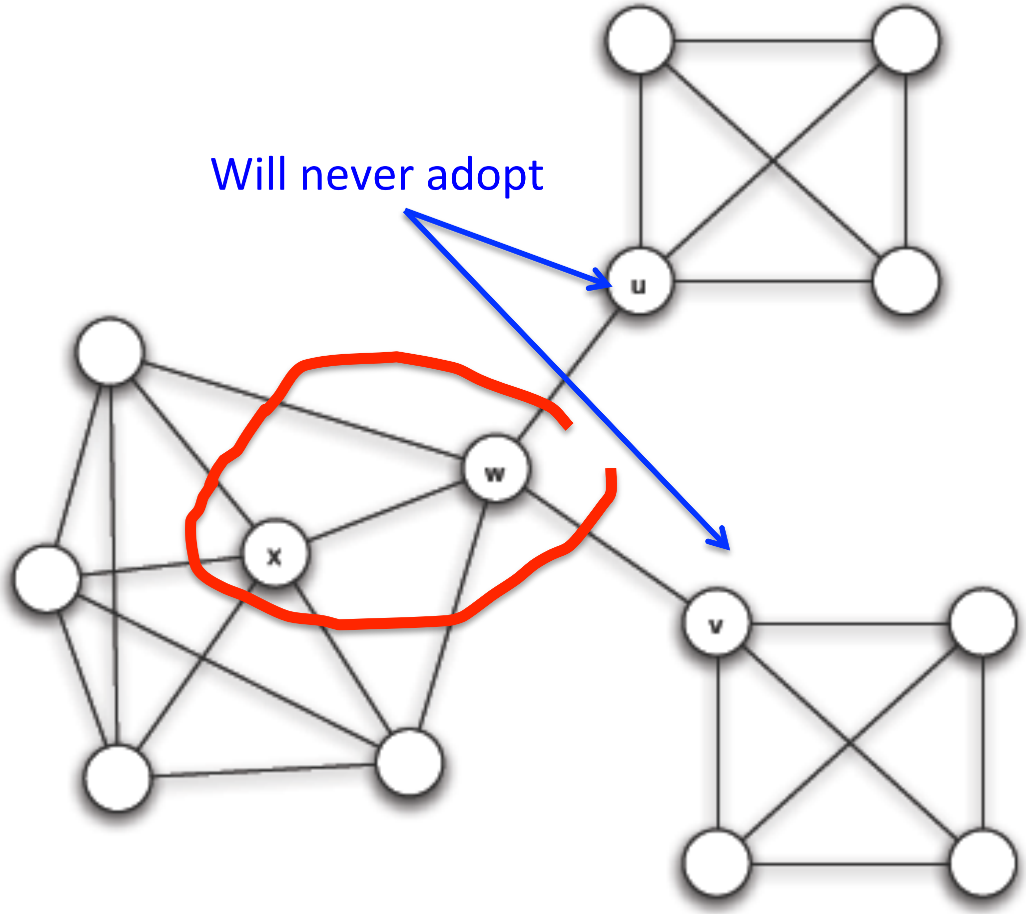
Adoption of hybrid corn

Role of Weak Ties

- v, w initial adopters
- q=1/2



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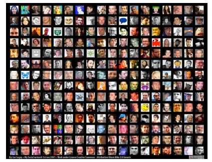
Weak Ties Role and Behaviour Adoption



- Weak ties are very powerful in spreading new information.
- Weak ties are weak at transmitting behaviours that are somehow risky and costly to adopt.

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Heterogeneous Threshold Model

- What if nodes value choices of different behaviour differently:

		w: A	w: B
v	A	a_v, a_w	$0, 0$
	B	$0, 0$	b_v, b_w

- Then $$p \geq \frac{b_v}{a_v + b_v}.$$
- **Each node will have a different threshold (q_v)!**
- **Blocking cluster:** set of nodes (v) which have more than 1-q_v neighbours in the set (where q_v is different for each of the nodes!).
- Similar rule about complete cascade can be defined using the blocking cluster concept.

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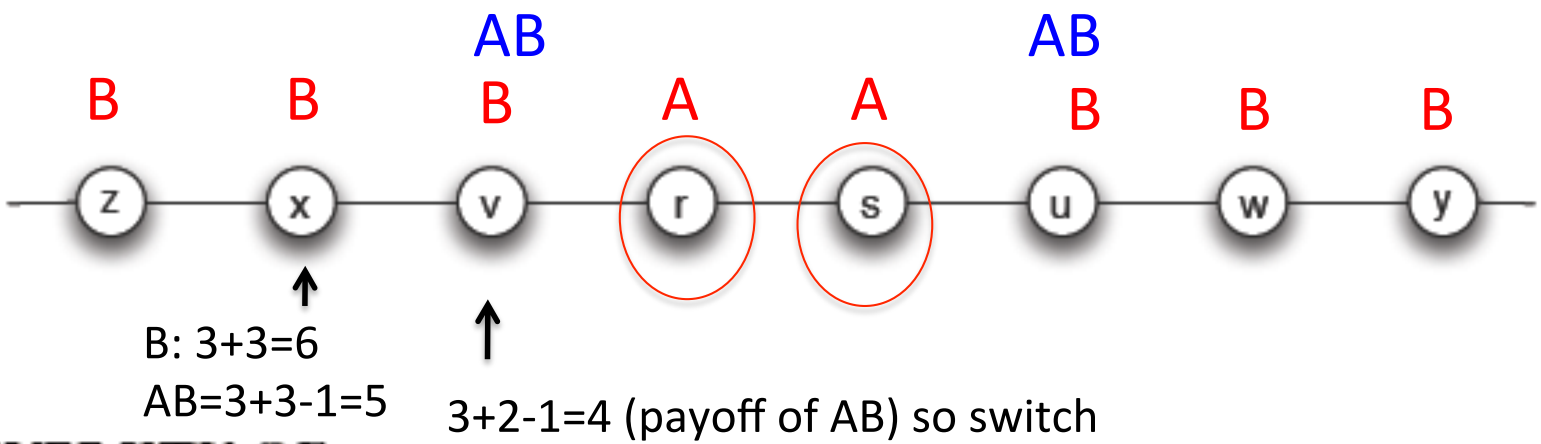
Cascades and Compatibility

- Example of Bilingual behaviour
  - In some cases nodes may want to play 2 strategies

		w: A	B	AB
v	A	a, a	$0, 0$	a, a
	B	$0, 0$	b, b	b, b
	AB	a, a	b, b	$(a, b)^{+}, (a, b)^{+}$

← Max(a,b)



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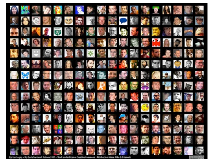
a=2, b=3, c (cost of keeping AB)=1



Another Example

-

Start	B	B	B	A	A	B	B	B
Step 1	B	B	AB	A	A	AB	B	B
Step 2	B	AB	AB	A	A	AB	AB	B
Step 3	AB	AB	A	A	A	A	AB	AB
Step 4	AB	A	A	A	A	A	A	AB

B will slowly disappear!

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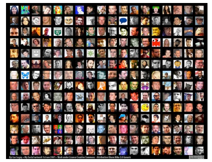
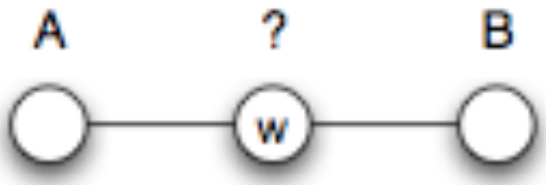
A=5, b=3, c (cost of keeping AB)=1

Capacity of Cascades (A,B, AB case)

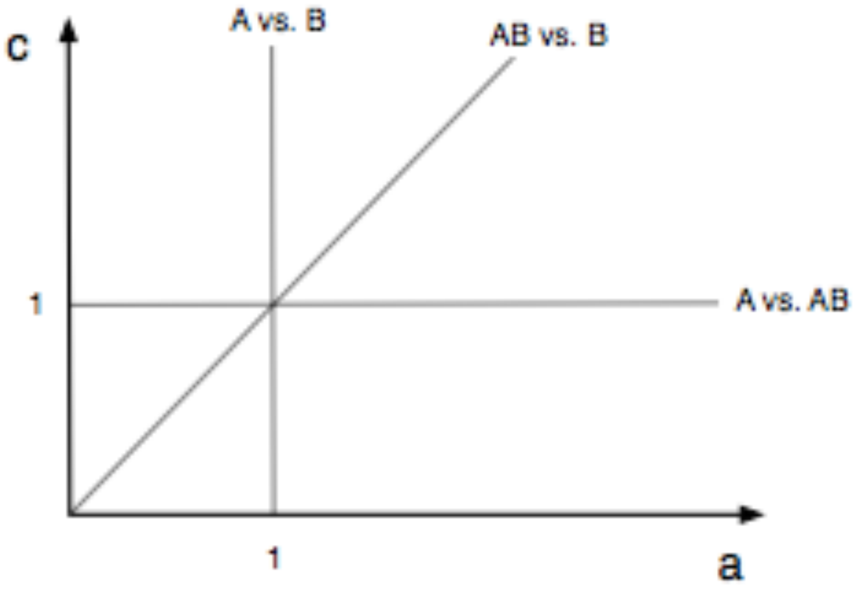


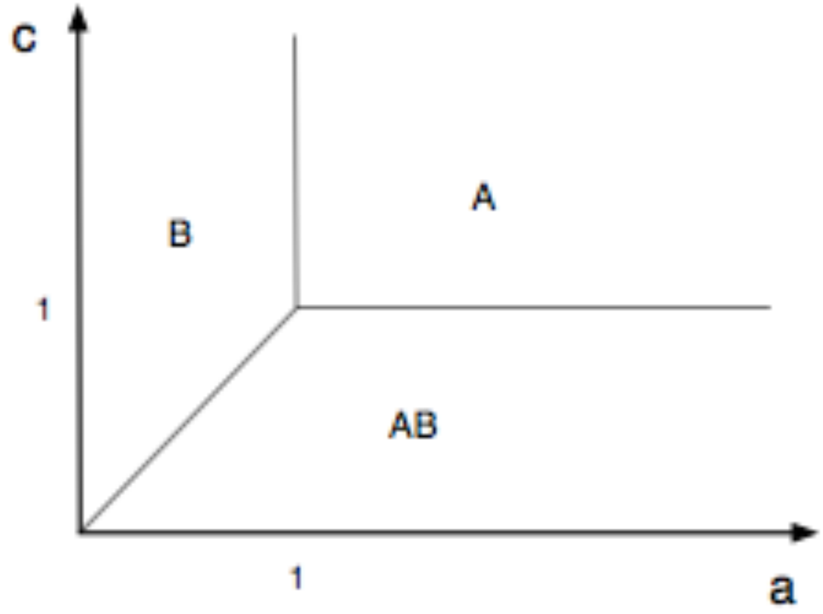
- Let’s fix b to 1 for simplicity.
- In this case it all depends on the relationship between a and c.
- What is the best strategy for node w in the following example?



payoff from choosing A: a
payoff from choosing B: 1
payoff from choosing AB: a + 1 - c

Dependency on a and c





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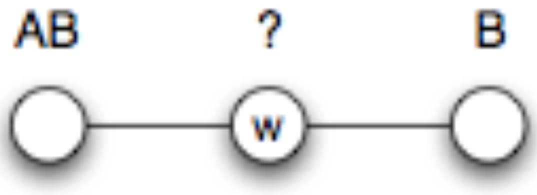
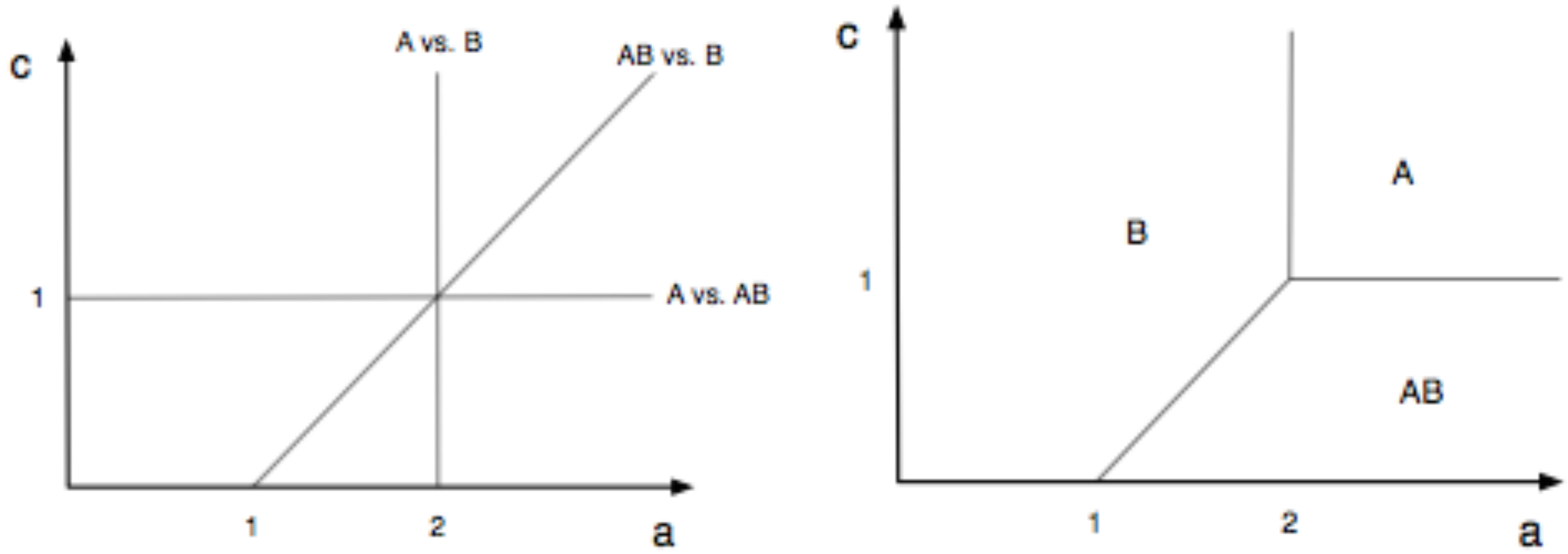
Second case

- Payoff of B is now 2 as it can interact on both sides:



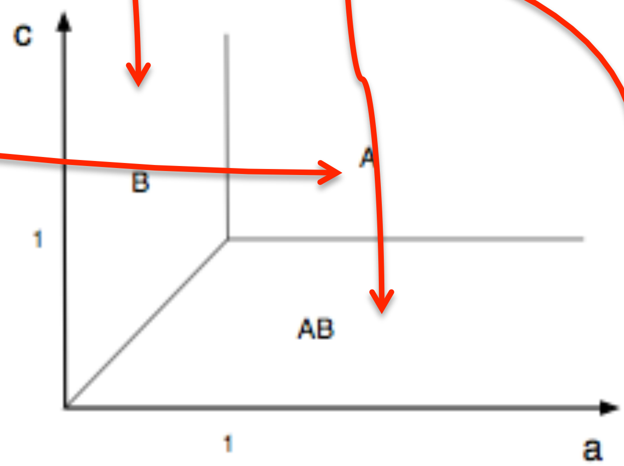
payoff from choosing A: a
payoff from choosing B: 2
payoff from choosing AB: a + 1 - c (if A is better)

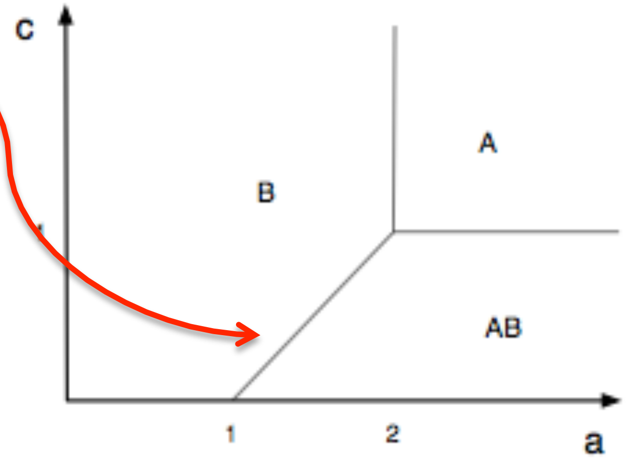
Graphically again…



For what pair (a,c) does A spread?

- Consider u adjacent to initial adopter of A
- Here B will stay
- Here A will spread to the network (cascade)
- Node u will behave like here, but his next neighbour will be like here (but same values of a and c).





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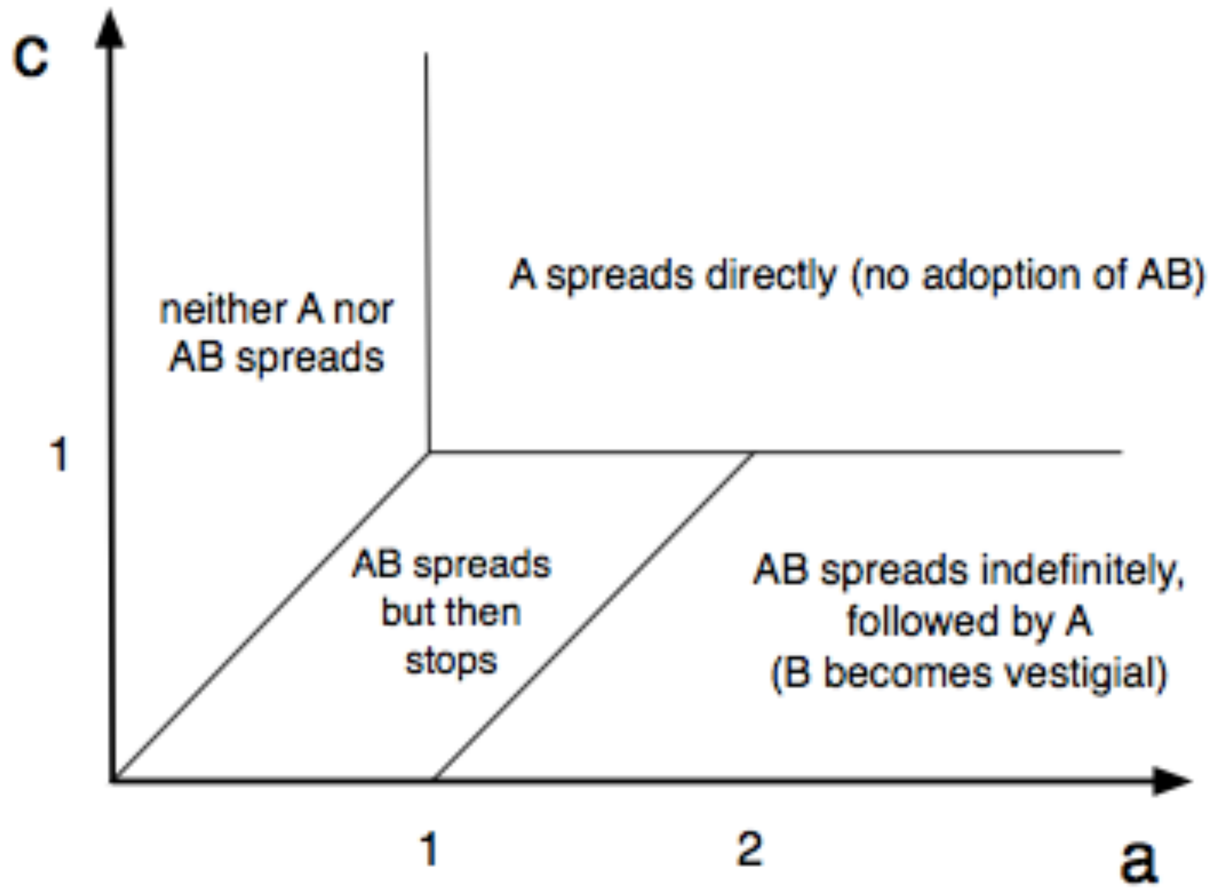
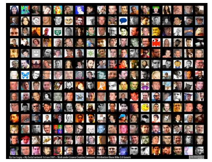
Summary


c
1
neither A nor AB spreads
A spreads directly (no adoption of AB)
AB spreads but then stops
AB spreads indefinitely, followed by A (B becomes vestigial)
1
2
a



Discussion

- Tips for technology producers
  - Suppose b=1 and a=1.5 [new technology]
  - For which values of c is B surviving?
- If easy to maintain both technologies [they are compatible] then AB will spread and then A [as it is better].
- If incompatible boundary people will choose [some will choose A] and this will spread.
- If in between some regions will maintain B and some will switch and there will be a bilingual buffer in between.

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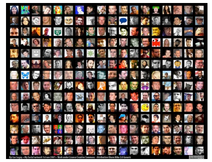
References



- Chapter 19

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