A Privacy-Preserving Social-Aware Incentive System for Word-of-Mouth Advertisement Dissemination on Smart Mobile Devices

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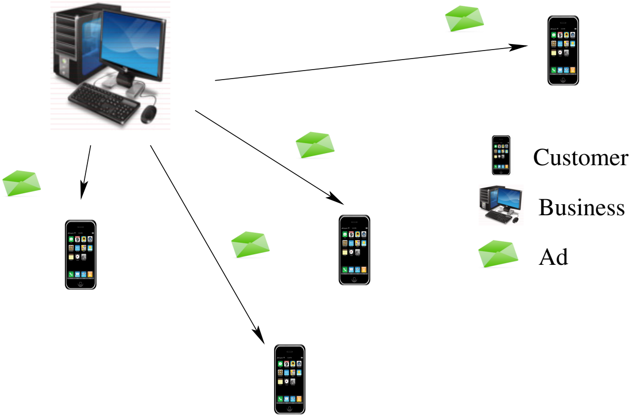
21 June 2012

Smartphones allow innovative advertising.

From the **direct** model (**B2C**)...



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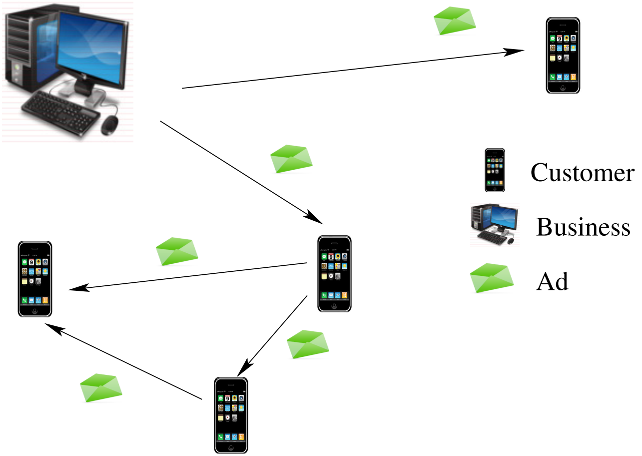

Word-of-mouth?

cost effectiveness + user intelligence

“. . . , send forth thy word, and let it fly.”

— Thomas Gibbons

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cost effectiveness + user intelligence

Our friends know us better than strangers.

What is interesting for a computer scientist?

- Incentive.
  - Why shall a user care?
  - Align the interests of users and businesses.
  - Encourage users to invite their interested friends.
  - Encourage businesses by empowering them with control over budget.
  - No spamming, please.
- Enforcement.
  - Detect misbehavior.
  - No one takes blame for others' wrongdoings.
- Privacy.
  - Do not inadvertently divulge relationship to strangers.

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Incentive tickets, aka **coupons**.

A user can **redeem** a coupon (when **paying** for a service/merchandise) or **duplicate** it.

Content T_C	What is the coupon good for?
Spray width W_C	Duplication restriction.
Available slots L_C	Number of available slots.
Authentication slots	For authentication.

Assume a Public-key Infrastructure (PKI).

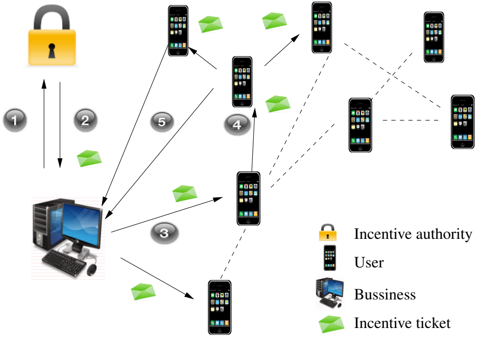
Just in case you read this later...

I	The incentive authority.
s	A shop.
u, v, w	Users.
p_u	User u's redemption probability.
k_u	The number of user u's contacts.
M	A text segment.
$M_1\|M_2$	Concatenation of text segments.
C_n	coupon cached by n.
T_C	Front-page section of coupon C.
W_C	Spray width of coupon C.
L_C	Available slots of coupon C.
K_n^+/K_n^-	n's public/private key.
$\{M\}_{K_n^-}$	n's digital signature on the hash of M.
$E_I(M)$	Encrypt M with I's public key.
x_n	A cryptographic nonce generated by n.
R_C	Reward amount for coupon C.
$i_1, i_2, \cdots, i_l$	Identifiers in coupon circulation chain.

A coupon's life cycle.

1. Shop s **requests** a coupon from authority I.

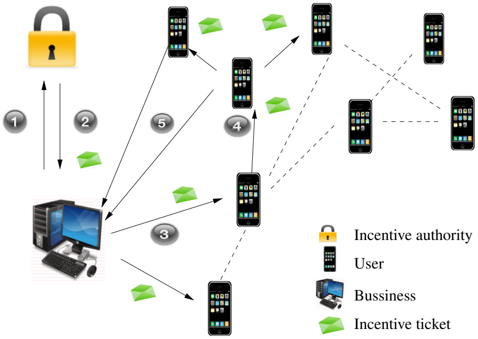
$$s \to I : \quad T_C, W_C, L_C$$



A coupon's life cycle.

2. Authority I **issues** the coupon to shop s.

$$C_s = \begin{array}{r} T_C, W_C|(L_C - 1), \\ E_I(\{T_C|W_C|L_C|s\}_{K_I^-}|x_s|I|s). \end{array}$$



A coupon's life cycle.

3. Shop s **offers** the coupon to user u.

$$
\begin{aligned}
C_u = \quad & T_C, W_C|(L_C - 2), \\
& E_I(\{C_s|u\}_{K_s^-}|x_u|s|u) \\
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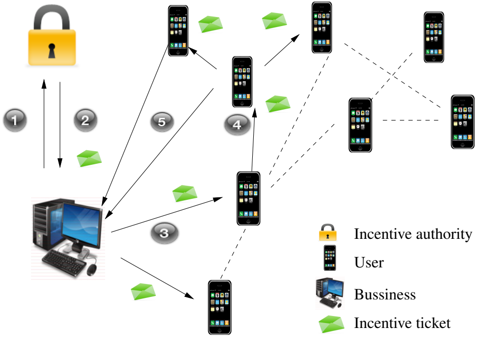
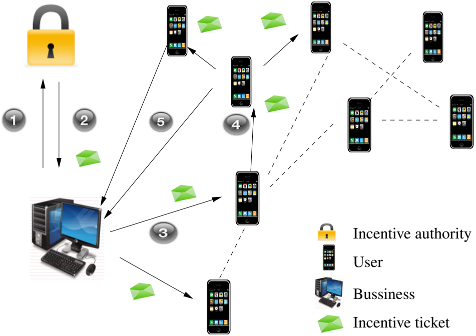


A coupon's life cycle.

4. User u **duplicates** the coupon to user v.

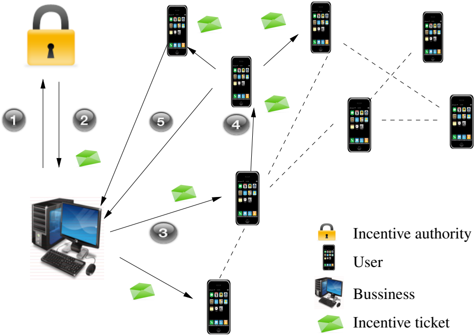
$$\begin{aligned} C_v = \quad & T_C, W_C|(L_C - 3), \\ & E_I(\{C_u|v\}_{K_u^-}|x_v|u|v) \\ & |E_I(\{C_s|u\}_{K_s^-}|x_u|s|u) \\ & |E_I(\{T_C|W_C|L_C|s\}_{K_I^-}|x_s|I|s). \end{aligned}$$



A coupon's life cycle.

5. User v **redeems** the coupon at shop s.

$$v \to s : \quad C_v$$



Prior-redemption verification.

Authority I **iteratively** decrypts each slot and reconstructs the coupon's **circulation chain** starting from the shop s.

Protocol-compliant behaviors.

- Verify before accepting.
- Signing transfers responsibility.
- Never over-duplicate.

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What if...?

Tampering.

- $\cdots \to u \to v \to w \to \cdots$.
- u and w are honest. v is malicious and tampers with the coupon.
- u's signature protects u from being framed by u.
- v's signature holds v responsible for tampering.

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Collusion.

- $\cdots \to u \to v \to \cdots$.
- v is honest. u is malicious, tampers with the coupon, and **colludes** with w by having w sign the tampered coupon.
- v will not notice.
- u will not be detected for misbehavior in verification...
- ...but w **will** be.
- Nobody wants to be **scapegoat**: w will not vouch for u.

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- Signatures hold users accountable
- Encryption keeps identifiers concealed.
- Abiding by the protocol is in each user's best interest.
- The circulation chain reconstructed from a redeemed incentive ticket faithfully reflects the incentive ticket's circulation among users

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- **Who** should be rewarded?
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Where?

From the shop's **profits in sales** where a coupon is redeemed: Shop s tells authority I the reward upper limit R_C.

- Only reward effective advertisement.
- Budget control: think about real-world coupon ("duplication not valid").

Who?

$$s = i_1 \to i_2 \to \cdots \to i_l \ (l \leq L_C)$$

$i_2, \cdots, i_{l-1}$ are rewarded for their effort of **duplicating**.

How?

- Uniform.
  - Everybody receives the **same**.
  - Disadvantage: **diminished attractiveness** and **looping strategy**.
- Geometric.
  - $p : 1$ between consecutive users $(0 < p < 1)$.
  - $p \approx 1$: degenerate to **uniform**.
  - $p \approx 0$: degenerate to **single-level** scheme; under-use user intelligence.
- Social-aware.
  - Insight: Reward level should be **fixed** and as **few** as **full** user-intelligence utilization allows.
  - Privacy mandates the level to be **2**.
  - $i_1 \to i_2 \to \cdots \to i_l$ $(l \geq 2)$.
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  - Insight: Reward level should be **fixed** and as **few** as **full** user-intelligence utilization allows.
  - Privacy mandates the level to be **2**.
  - $i_1 \to i_2 \to \cdots \to i_l$ $(l \geq 2)$.
  - $l \geq 4$: i_{l-1} gets $\frac{1}{1+\alpha} R_C$; i_{l-2} gets $\frac{\alpha}{1+\alpha} R_C$. $l = 3$: i_{l-1} gets $\frac{1}{1+\alpha} R_C$. $l = 2$: no rewards.
  - α: social weight.

Adam Smith's invisible hand metaphor.

If users and the shop share the same estimation about redemption probability distribution in the population, a ***social weight*** $\alpha = 1$ *will lead to a* ***desirable*** *situation in which a user,* ***acting on his own interest****, serves the shop's interest best.*

Questions?

Thank you for your attention!