Timing Game Aspects of Conversational Interactivity

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Overview

- Introduction and motivation
- Conversation as renewal process
- Game-theoretic model
- The case of asymmetric information
- Interactivity as utility maximization
- Conclusions

Motivation

- General context: Charging for Quality-of-Experience (QoX) of telecommunication services
- Example: Voice-over-IP
- Our focus: QoX and conversational interactivity

- Question 1: What is interactivity?
- Question 2: How to measure it?
- Question 3: Impact on QoX? And how to use it for charging purposes?

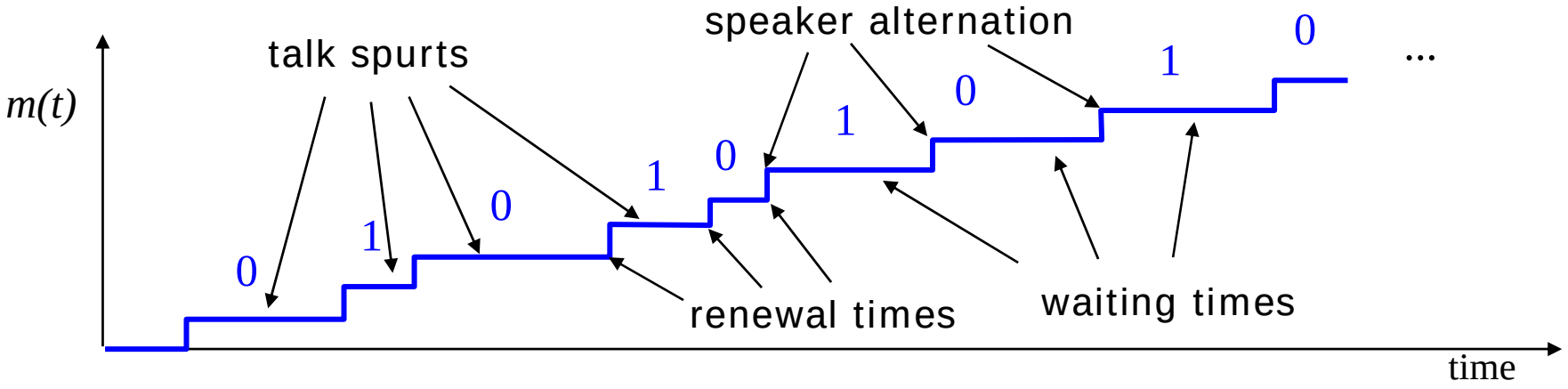
State of the Art

- 20 years ago: “Interactivity is a widely used term with an intuitive appeal, but is an under-defined concept ... it has high face validity, but only narrowly based explication, little consensus on meaning and only recently emerging empirical verification of actual role.“ [S. Rafaeli 1988]

- Today: still only intuitive general understanding of what is interactivity, but
  - lack of proper technical definition
  - lack of feasible and reproducible metrics

Renewal Model

- First idea: conversation as Renewal Process
  - Waiting times = talk spurts
  - Renewal times = speaker alternations



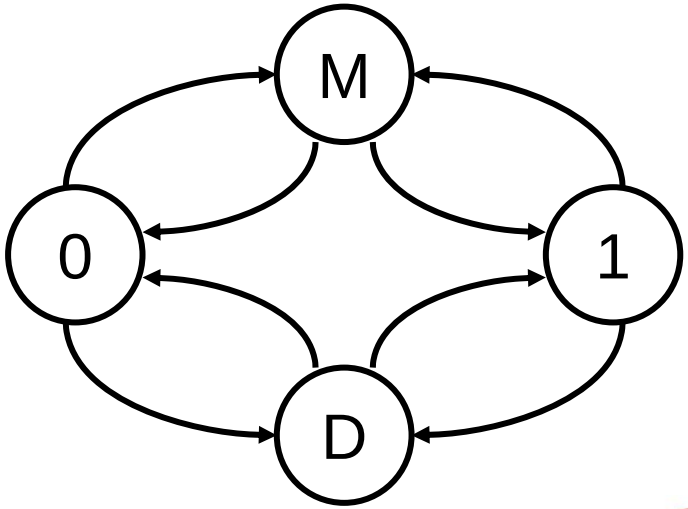
- Elementary Renewal Theorem: $\lim_{t\to\infty} \frac{m(t)}{t} = \frac{1}{\delta}$

- Related metric: Speaker Alternation Rate (SAR)

Bilateral Conversations

- So far: very simple model (only 2 states)
- But: standard ITU-T conversation model (Rec. P.59)
  - two participants: #0 and #1
  - players are either speaking or listening at a time
  - four resulting states:
    0, 1, M (mutual silence), D (double talk)

	#0 speaking	#0 listening
#1 speaking	D	1
#1 listening	0	M



Game-theoretic Model

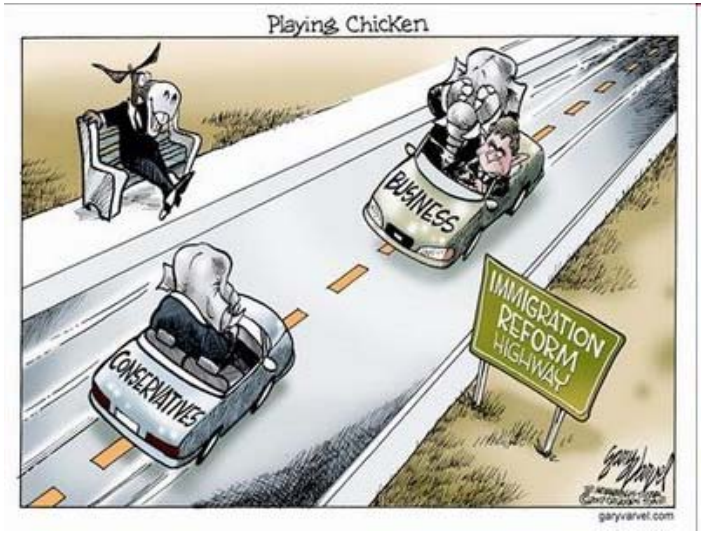
- Idea: semantic model + game theory

  conversation = game between two players who aim at maximizing their individual utilities (gained from mutual exchange of content)

- Context: Timing Games

  → „stop“ action as only strategic choice

  → notorious example: chicken game

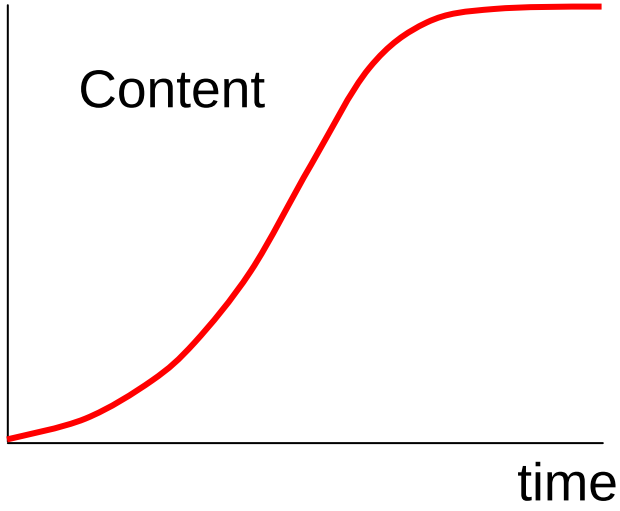


Model Details

- Players either in „speaking“ or „listening“ state
- Players decide continuously and independently whether to change their state or to remain in present state
- „Content drives intensity“

  $\rightarrow$ talk spurt described by logistic function (sigmoid)

  with $C(0) = 0$ and $\lim_{t \to \infty} C(t) = C$



$$\rightarrow \quad C(t) = \left(\frac{\gamma/(\gamma-1)}{\left(1+\kappa \exp(-\rho(t-\mu))\right)^{1/\kappa}} - \frac{\gamma}{\gamma-1} \right) \cdot C$$

with $\gamma = \left(1+\kappa \exp(\rho\mu)\right)^{1/\kappa}$

Model Details (cont'd)

- Sender: intensity = derivative of content function

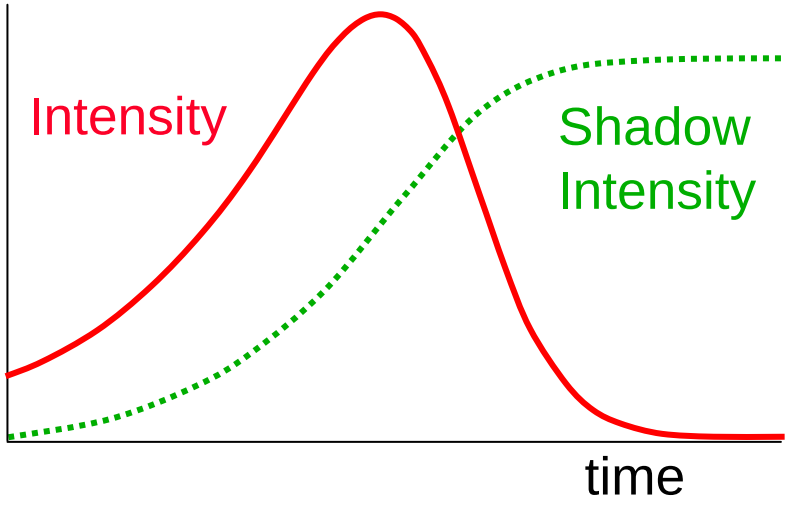
$$I(t) = \frac{d}{dt}C(t) = \frac{\gamma}{\gamma - 1}\left(\frac{\rho \exp(-\rho(t-\mu))}{\left(1+\kappa \exp(-\rho(t-\mu))\right)^{1+1/\kappa}}\right) \cdot C$$

- Receiver: latent intensity („shadow intensity") directly proportional to received content

$$\bar{I}(t) = \bar{I}_0 \cdot \bar{C}_t$$

with

$$\bar{I}_0 = \bar{I}(0) = \frac{\bar{\rho}}{\bar{\kappa}} \cdot \frac{\bar{\gamma}^{\bar{\kappa}} - 1}{\bar{\gamma}^{\bar{\kappa}+1} - \bar{\gamma}^{\bar{\kappa}}}$$

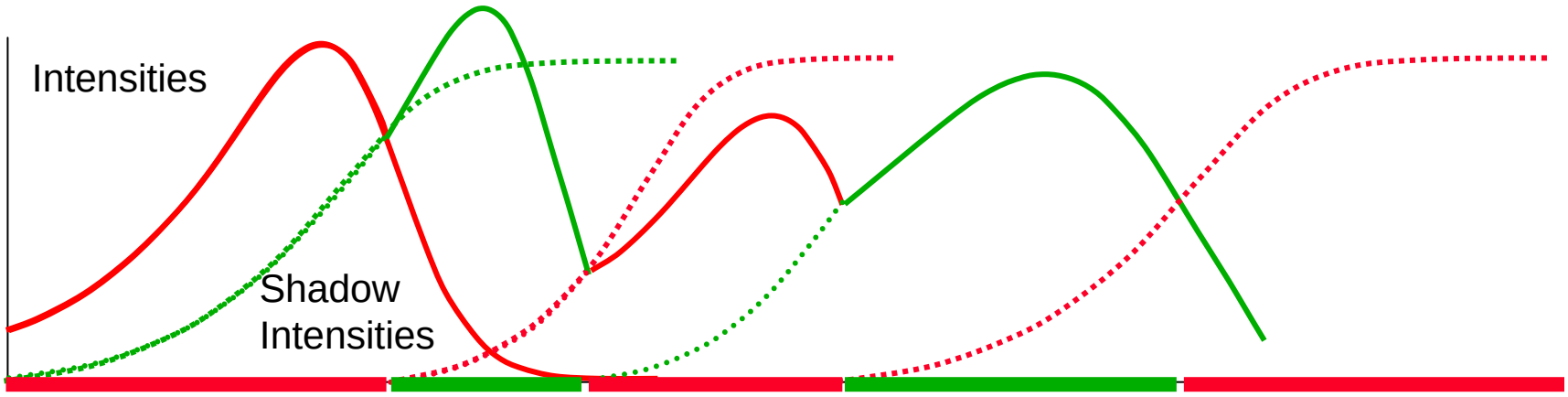


Talk Spurt Utility

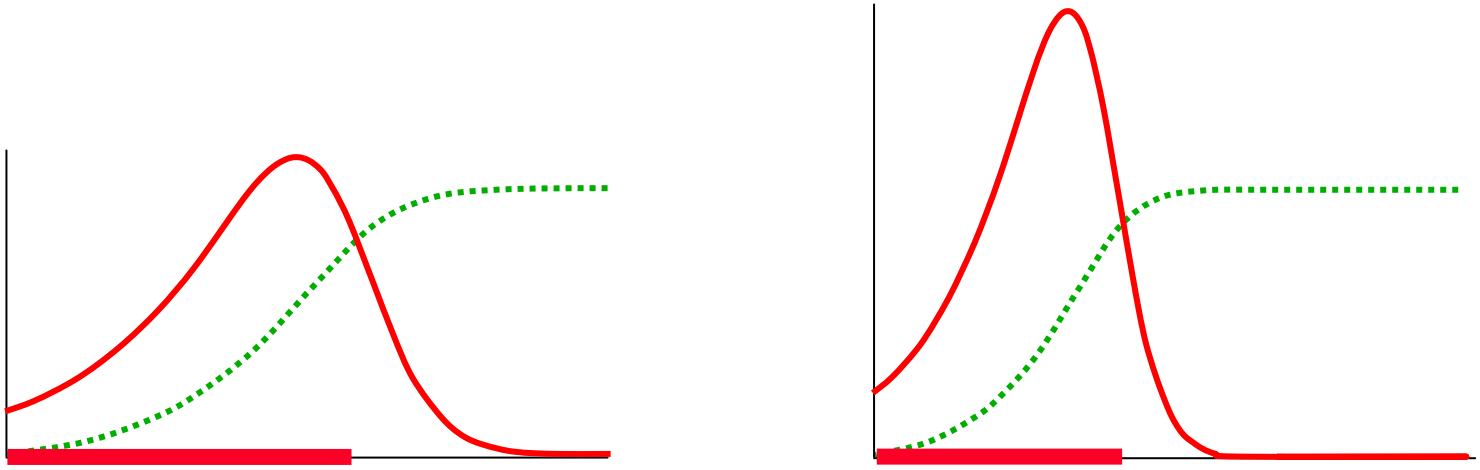
- Assumption: utility of talk spurt n
  = total content sent/received during T_n

$$\rightarrow \quad U_n(T_n) = \int_{t=0}^{T_n} I(t)dt$$

- Idea: maximize utility for entire conversation
- Optimal behaviour: speaker alternation for $I(T_n) = \bar{I}(T_n)$



Effect of Intensity Increase



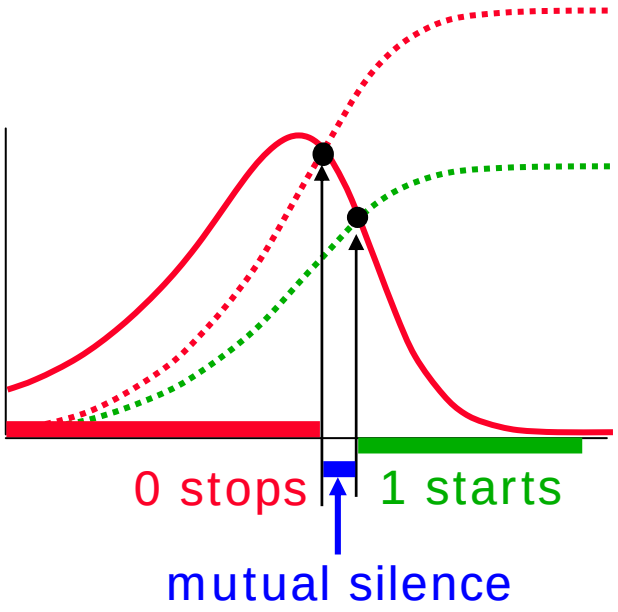
- Increase of intensity implies two effects:
  - Reduction of talk spurt length
  - Increase of total transmitted content per talk spurt
- Conclusion: the shorter the talk spurts, the more efficient the conversation

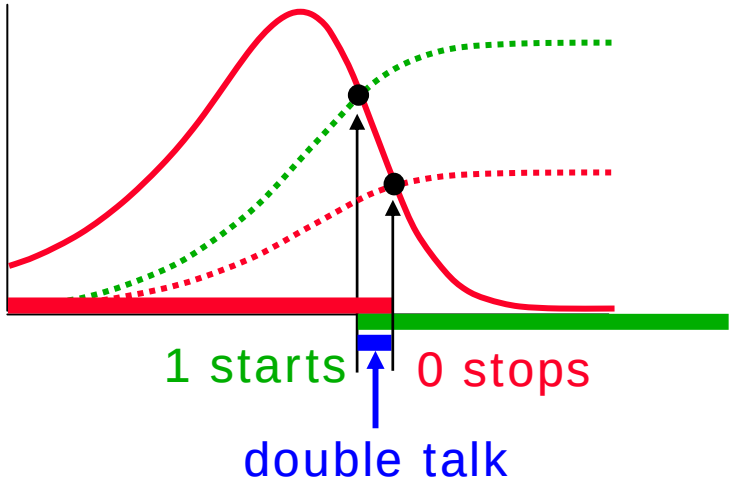
Asymmetric Information

- So far: alternation between states „0“ and „1“
- Remember: each player decides individually about changing her status (listening/speaking)
- But: in order to maximize utility, each player needs to know about the intensity / shadow intensity of the other one
- Ideally: both optimization processes coincide
- Reality: best guess, of course!!!

Asymmetric Information (cont'd)

- Assume player 0 (current speaker) makes erroneous guess about shadow intensity
  - Option 1: overestimation
  - Option 2: underestimation



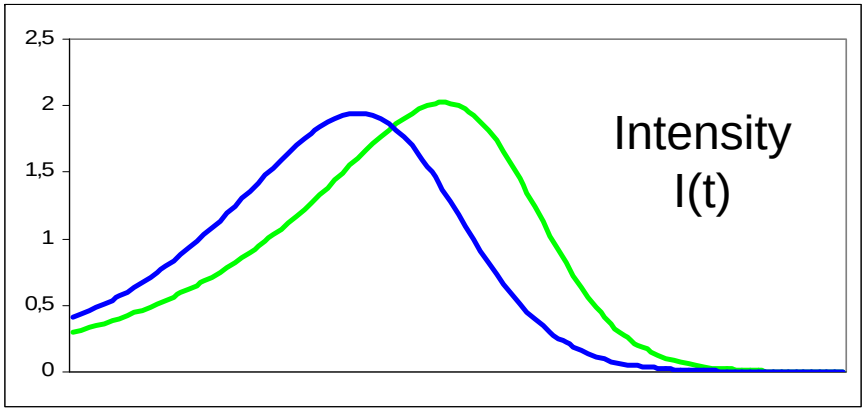


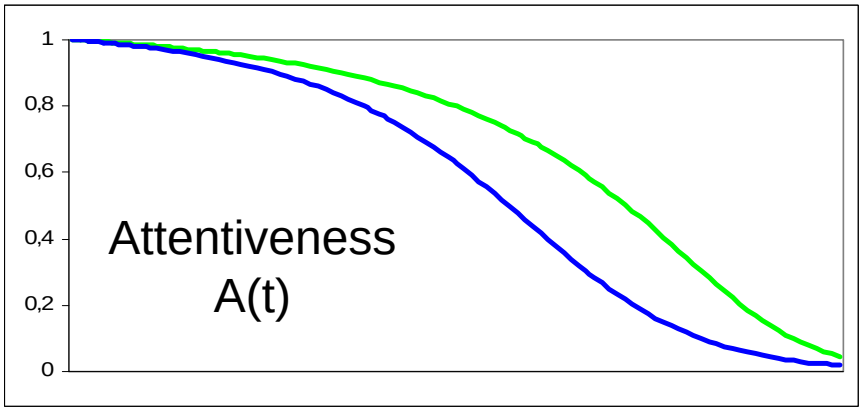
Model Refinement

- Utility of player i depends also on attentiveness of player 1-i
- Idea:

→ Intensity = 1st derivative of logistic function

→ Attentiveness = reverse logistic function





- Note: $I(t) \cdot A(t)$ has exactly one maximum

Interactivity as Utility Maximization

- Then: define utility in terms of the product of sender intensity and listener attentiveness

$$U_i = \int_0^{T_n} I_i(t) \cdot A_{1-i}(t)\, dt$$

- Total utility for conversation of length T = sum of utilities during individual talk spurts T_n

- Resulting optimization problem:

$$\max \{U(T)\} \text{ over } \{N; T_1, \ldots, T_N\} \text{ such that } \sum_{n=1}^{N} T_n = T$$

What have we learned?

- Conversational interactivity as an important and characteristic feature of communication services
- Game-theoretic model: content drives intensity
- Asymmetric information: full conversation model
- Further work:
  - Metrics for conversational interactivity
  - Impact on Quality-of-Experience and related pricing models
  - Integration into instrumental evaluation tools for Quality-of-Experience

Thank you very much for your attention!