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Trust Assessment of Smart Health Devices

Final presentation

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Plan

Introduction

Use cases of Smart Health devices

Trust

Architecture and risks of Health Monitoring Systems

Trust Networks

Summing up

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Summing up

Introduction

- Smart health systems are evolving rapidly
- Impact lives in different ways
  - Saving life
  - Improving life or performance
  - Data monitoring

Introduction - The Pacemaker

- Bradycardia: heart rate too slow
- Pacemaker provides electrical impulse

  → keep heart rate from dropping
- IoT pacemaker: wireless connection
  - exchange information with hospital and doctors
  - can be remotely monitored
- Replace regular visits to the doctor's office for a check with the remote monitoring?
- How far can we **trust this device** to function properly at all times and how can we **assess trust** in them?

Introduction - Problem

- Trust is a complex subject
- Many works propose different mathematical methods
- Focus on TNA-SL (Trust Network Analysis using Subjective Logic)
  - method for quantifying trust
  - covered in different works in literature
  - can be applied on IoT and smart health networks

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Use cases of Smart Health devices

- Specific medical condition
  - SMARTDIAB against diabetes: insulin therapy
  - heart rate monitoring (remote and real-time)
- Vital signs
  - electrocardiogram
  - blood pressure
  - temperature
- Smart technologies
  - ECG on mattress
  - toilet seats
  - pillows

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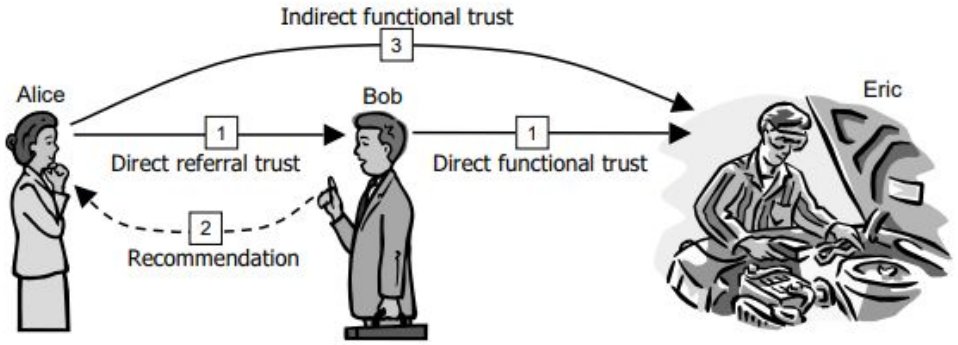
Trust

Definition: “a state involving confident positive expectations about another’s motives with respect to oneself in situations entailing risk”
(D Susan and John G Holmes, 1991)

- Trust relationship involves two or more entities:
  a trustor and a trustee
- Trust involves risk
- Trustor believes in the trustee’s honesty and benevolence

Trust - Characteristics



- Directed: oriented relationship
- Subjective
- Context-dependant
- Measurable
- Influenced by past experience
- Dynamic: may change over time

Trust - Modeling and management

Trust model

- Evaluates, sets up trust relationships amongst entities in order to calculate trust
- Helps in trust measurement
- Many works propose different models for different goals

Trust management

- *Trust establishment*: trust relationship between trustor and trustee
- *Trust monitoring*: performance of trustee, collect evidence for
- *Trust assessment*: evaluate trustworthiness of trustee
- *Trust control and re-establishment*: trust relationship in case broken before

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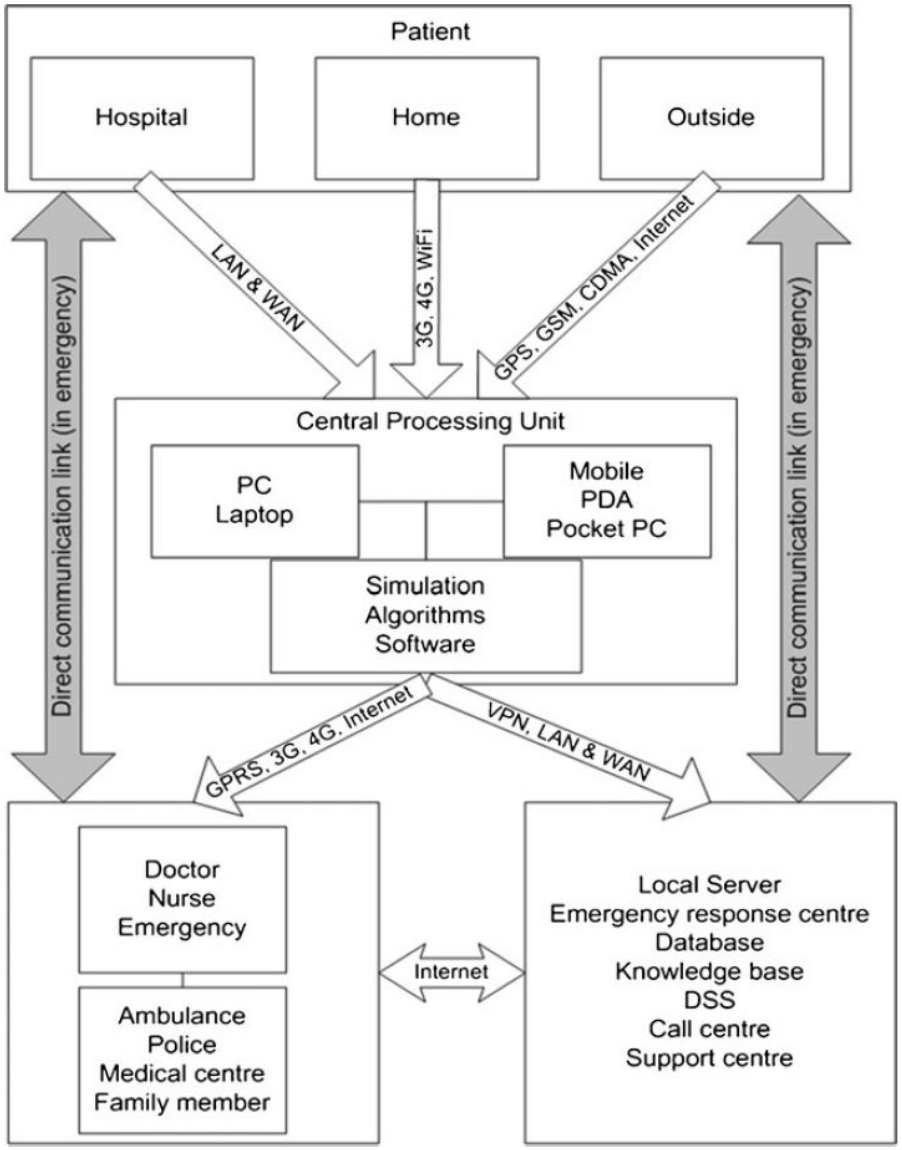

- Patient Unit
- Central Processing Unit
- Doctor and Emergency Units

Risks

- System shutdown
- Software error
- Unreliable communication
- Personal

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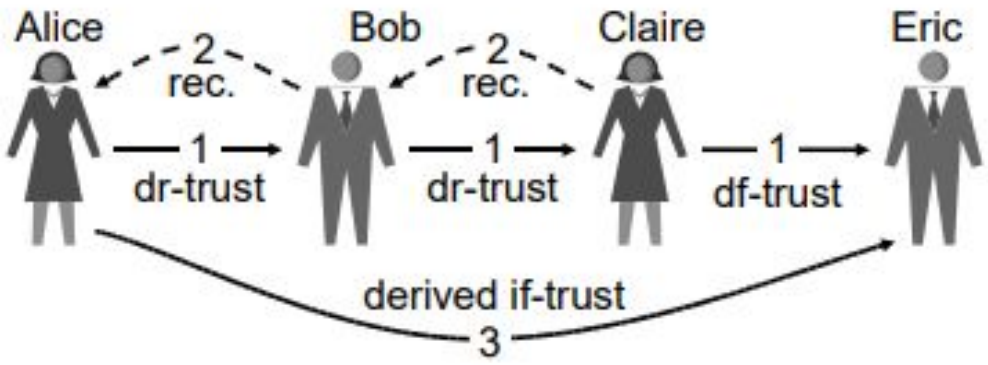
Trust Networks

- Many works propose different trust models
- TNA-SL (trust network analysis using subjective logic)
  - Transitive trust relationships between people, organizations and possibly software agents.
  - In examples we show the case of human trust

TNA-SL - Transitivity

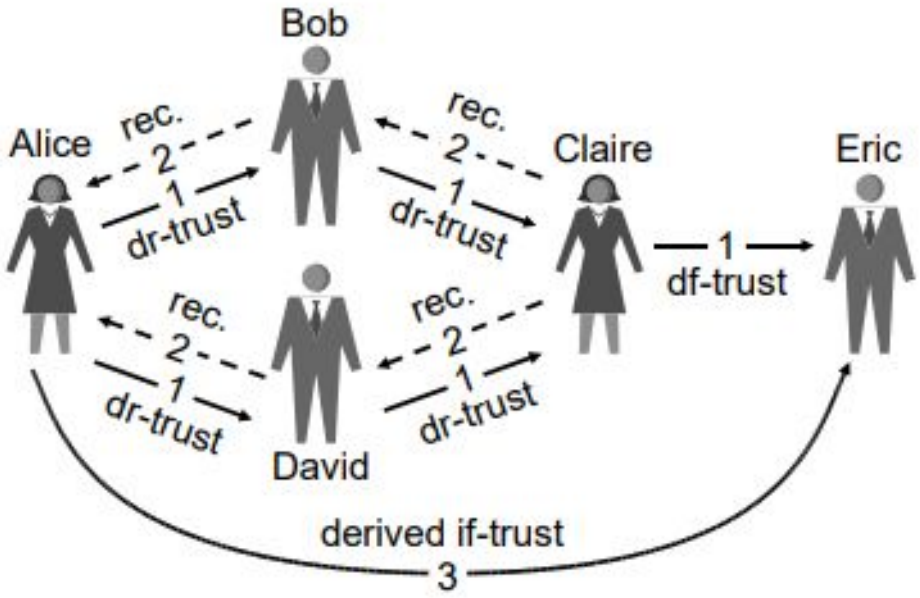


“.”

$$([A,E]) = ([A,B] : [B,C] : [C,E])$$

- Recommendation
- Trust scope
- Referal trust
- Functional trust

TNA-SL - Parallel trust combination



"◇"

$$([A,E]) = (([A,B] : [B,C]) \diamond ([A,D] : [D,C])) : [C,E]$$

TNA-SL - Subjective logic

Subjective logic: *belief calculus* used for calculative analysis trust networks

Belief theory

- related to probability theory
- the probabilities over the set of possible outcomes do not always add up to 1

Belief calculus

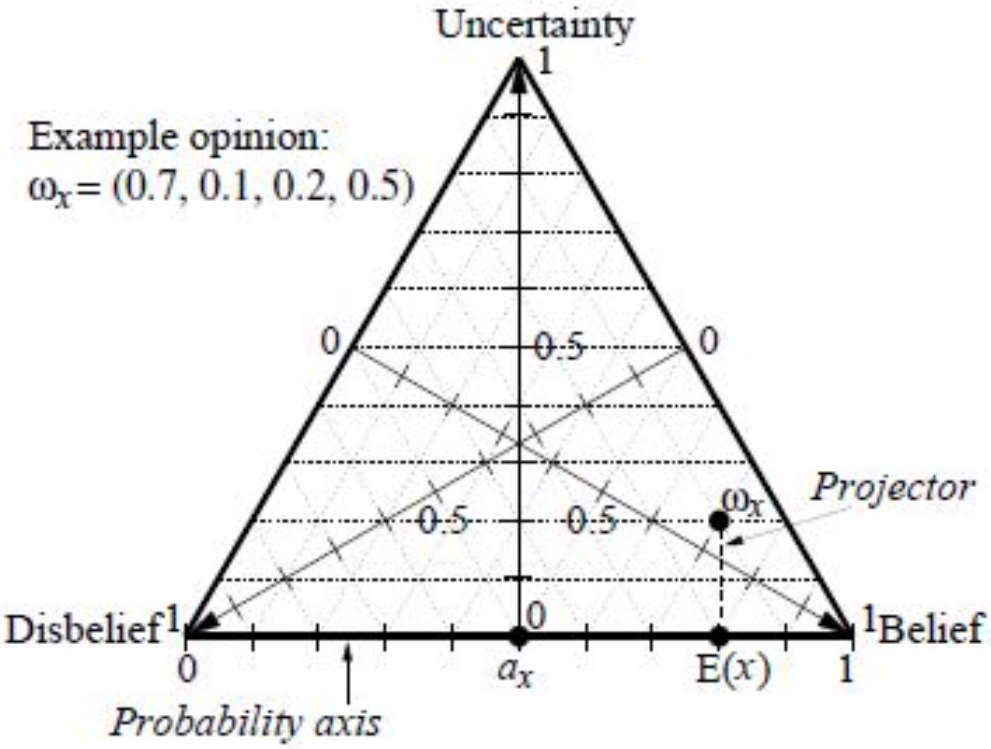
- approximate reasoning in situations with partial ignorance
- represented by *subjective logic* using **opinions**

TNA-SL - Opinion

$$\omega_x^A = (b, d, u, a)$$

- **A** is the *trustor* of the *statement* **x**
- **b** represents *belief*
- **d** represents *disbelief*
- **u** represents *uncertainty*, where $b, d, u \in [0, 1]$ and $b + d + u = 1$
- **a** ∈ [0, 1] is the *base rate*
  - represents the *initial trust* put in any member of the community before any positive or negative experience was observed.

TNA-SL - Subjective logic



$$E(\omega_x^A) = b + au$$

TNA-SL - Subjective logic

Two opinions $\boldsymbol{\omega}_x$ and $\boldsymbol{\omega}_y$ are ordered following rules by priority.
The greatest opinion is the opinion with:

- the greatest probability expectation
- the least uncertainty
- the least base rate

TNA-SL - PDF

Probability density function (PDF) denoted as (α,β):

$$\alpha = r + 2a, \beta = s + 2(1 - a)$$

- **r** represents a number of *positive* past observations
- **s** represents a number of *negative* past observations,

Can be expressed as:

(Audun Jøsang, Simon Pope, and David McAnally, 2006) & (Morris H DeGroot and Mark J Schervish, 2012)

$$\begin{cases} b_x = r/(r+s+2) \\ d_x = s/(r+s+2) \\ u_x = 2/(r+s+2) \\ a_x = \text{base rate of } x \end{cases} \iff \begin{cases} r = 2b_x/u_x \\ s = 2d_x/u_x \\ 1 = b_x + d_x + u_x \\ a = \text{base rate of } x \end{cases}$$

TNA-SL - Assessing trust

Reputation score of *Z* at time *t*:

$$R^t(Z) = \frac{r + 2a}{r + s + 2} \qquad \text{with } 0 \leq R^t(Z) \leq 1$$

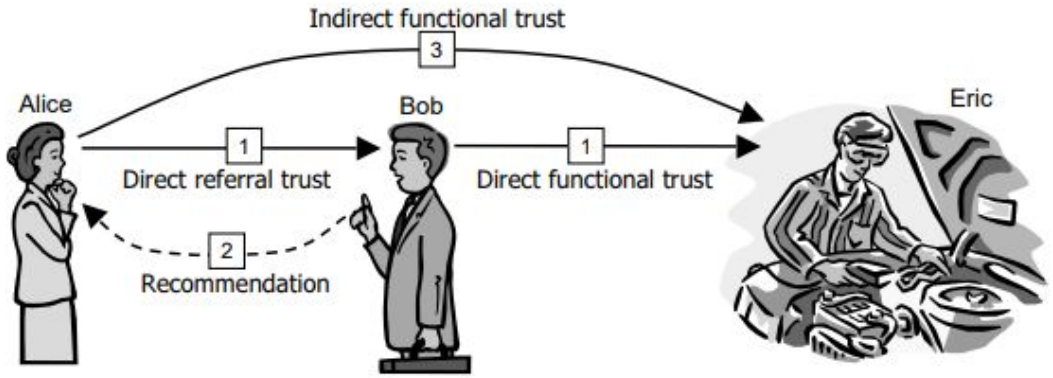
- probability indicating the reliability of an agent Z in the future
- a is high, that means the initial trust in the agent is relatively high, a single negative rating s will have more impact on the reputation score than a single positive rating r.
- On the other hand, if the base rate a is low, a single positive rating will have more impact than a single negative rating.
- “it takes many good experiences to balance out one bad experience”

TNA-SL - Applying to smart health

- Consists of transitive trust relationships betw.
  - people
  - organizations
  - software agents
- IoT perspective: entities represent components communicating with each other
- Applicable on different types of entities
  → usable for different types of network

Trust acts on different levels or hierarchies!

TNA-SL - Applying to smart health



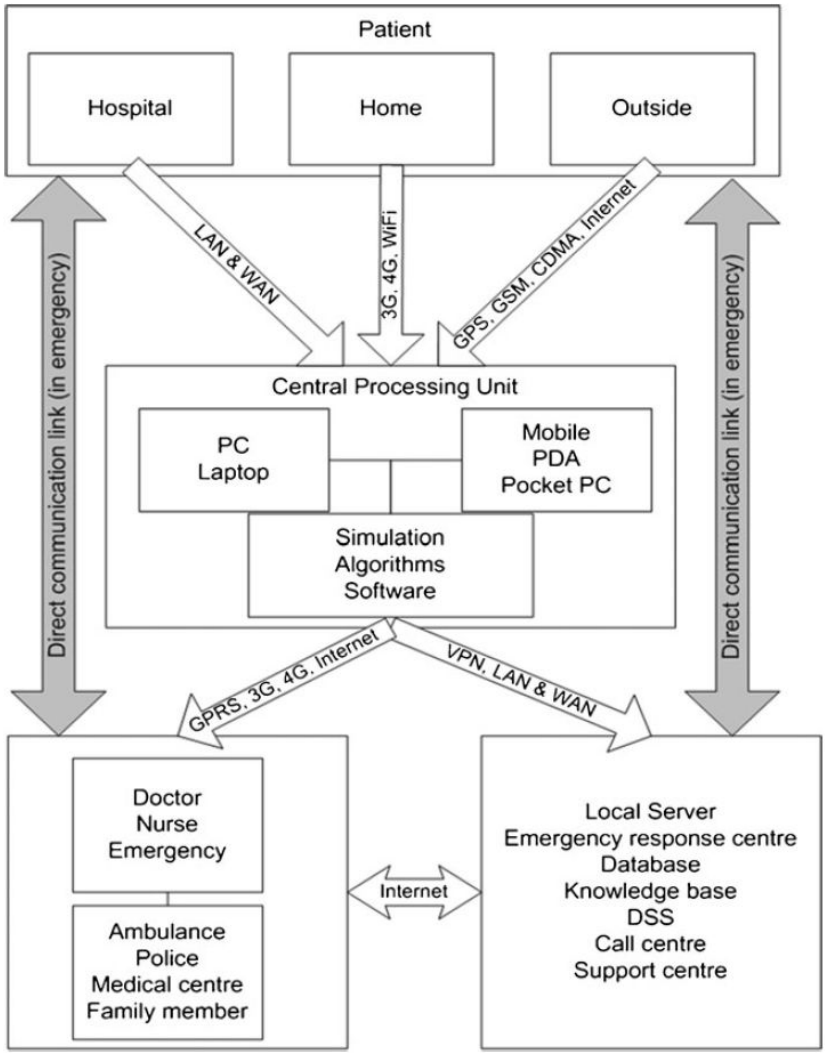
- Human trust
  - network of humans
  - some have direct functional trust towards a smart health device

TNA-SL - Applying to smart health

Component-based network (see Fig.)

- choose preferred unit for best result
- administrator can interpret which units need some improving

TNA-SL depends on the number of known relationships (Geir M Køien, 2011)
→ network with more entities has better result than a smaller one
→ For simple smart health IoT systems, this method is likely not effective



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- Introduced smart health with use cases
- Trust in IoT
- Architecture of health monitoring
- TNA-SL

Summing up - Perspectives

- Health IoT needs to be trustable on each layer of the architecture
- Malicious intent?
- Review different trust assessment models
- Research psychological difference on trust between using IoT and smart health IoT
- In-depth look in each aspect of trust
- Health monitoring architecture: go over each channel and unit and analyze reliability

Thank you!