Resolution of conflicts among ontology mappings: a fuzzy approach

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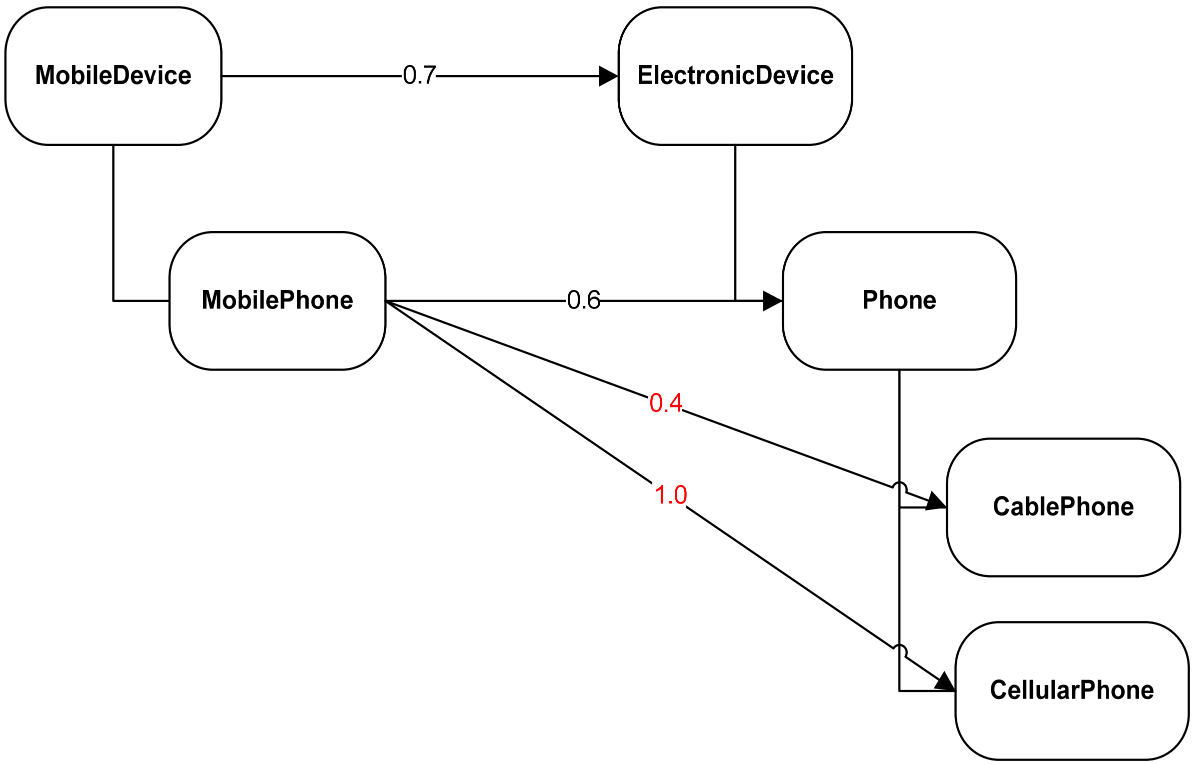
Conflicts

- Mappings can be incompatible



$$CablePhone \sqsubseteq \neg CellularPhone$$

Why Fuzzy?

- Automatic extraction of mappings creates degrees
- Can be considered as degrees of similarity
  - Fuzzy membership function

$$map(DarkGrey, Black, 0.8)$$

Related Work

- Mapping Validation [Meilicke C and Stuckenschmidt H, 07]
  - Used crisp method to create one-to-one mappings
- Use imperfection handling formalisms for representing degrees of mappings
  - Probabilistic Description Logics [Cali A et al., 07]
  - Fuzzy e-connections [Lu J et al. 07]
- Probabilities for mapping validation [Castano S et al. 07]

Motivation

- No fuzzy reasoner for e-connections exists
  - Use available fuzzy reasoners (FiRE)
- Probabilistic approaches do not capture the imprecision of similarity
- Propose different means to represent degrees using fuzzy description logics
- Conflicting mappings should be refined

Preliminaries

- Fuzzy Description Logics
- Fuzzy Subsumption

Fuzzy Description Logics

- Usual Tbox and RBox axioms:

$$T = \{Black \sqsubseteq DarkGrey,\ Car \equiv Automobil\}$$

- Abox: Fuzzy Assertions:

$$A = \{(a : Tall) \geq 0.8,\ ((a, b) : hasDarkHair) \leq 0.4\}$$

- Formal Semantics
  - $(C \sqcap D)^{\mathcal{I}}(a) = t(C^{\mathcal{I}}(a^{\mathcal{I}})), D^{\mathcal{I}}(a^{\mathcal{I}}), \text{t: fuzzy intersection (t-norm)}$
  - $(C \sqcup D)^{\mathcal{I}}(a) = u(C^{\mathcal{I}}(a^{\mathcal{I}})), D^{\mathcal{I}}(a^{\mathcal{I}}), \text{u: fuzzy conjunction (t-conorm)}$
  - $(\exists R.C)^{\mathcal{I}}(a) = \sup_{b \in \Delta^{\mathcal{I}}} t(R^{\mathcal{I}}(a^{\mathcal{I}}, b^{\mathcal{I}}), C^{\mathcal{I}}(b^{\mathcal{I}}))$
  - $(\forall R.C)^{\mathcal{I}}(a) = \inf_{b \in \Delta^{\mathcal{I}}} J(R^{\mathcal{I}}(a^{\mathcal{I}}, b^{\mathcal{I}}), C^{\mathcal{I}}(b^{\mathcal{I}})),\ J\text{: fuzzy implication}$

Fuzzy Subsumption

- Proposed by [Straccia, 01]
- Syntax
  - $\langle C \sqsubseteq D, n \rangle$
- Semantics
  - $\mathcal{I} \models \langle C \sqsubseteq D, n \rangle$ iff $\inf_{a \in \Delta^{\mathcal{I}}} J(C^{\mathcal{I}}(a), D^{\mathcal{I}}(a)) \geq n$
- Example
  - $\mathcal{I} \models \langle Black \sqsubseteq DarkGrey, 0.8 \rangle$

$$\text{iff } \inf_{colour \in \Delta^{\mathcal{I}}} J(Black^{\mathcal{I}}(colour), DarkGrey^{\mathcal{I}}(colour)) \geq 0.8$$

$$\Longleftrightarrow$$

$$t(Black^{\mathcal{I}}(colour), 0.8) \leq DarkGrey^{\mathcal{I}}(colour)$$

Fuzzy Mapping

- A fuzzy mapping fm = <C, C', R, n> is a mapping m whose value n denotes the degree that the semantic relation R holds between C, C' and where R can be one of equivalence ($\equiv$) or subsumption ($\sqsubseteq$, $\sqsupseteq$)
  - $C \xrightarrow{\equiv} C' : n$
  - $C \xrightarrow{\sqsubseteq} C' : n$
  - $C \xrightarrow{\sqsupseteq} C' : n$

Fuzzy Mapping Interpretation

- Provide semantics to the mappings
  - Formalize mappings as fuzzy knowledge

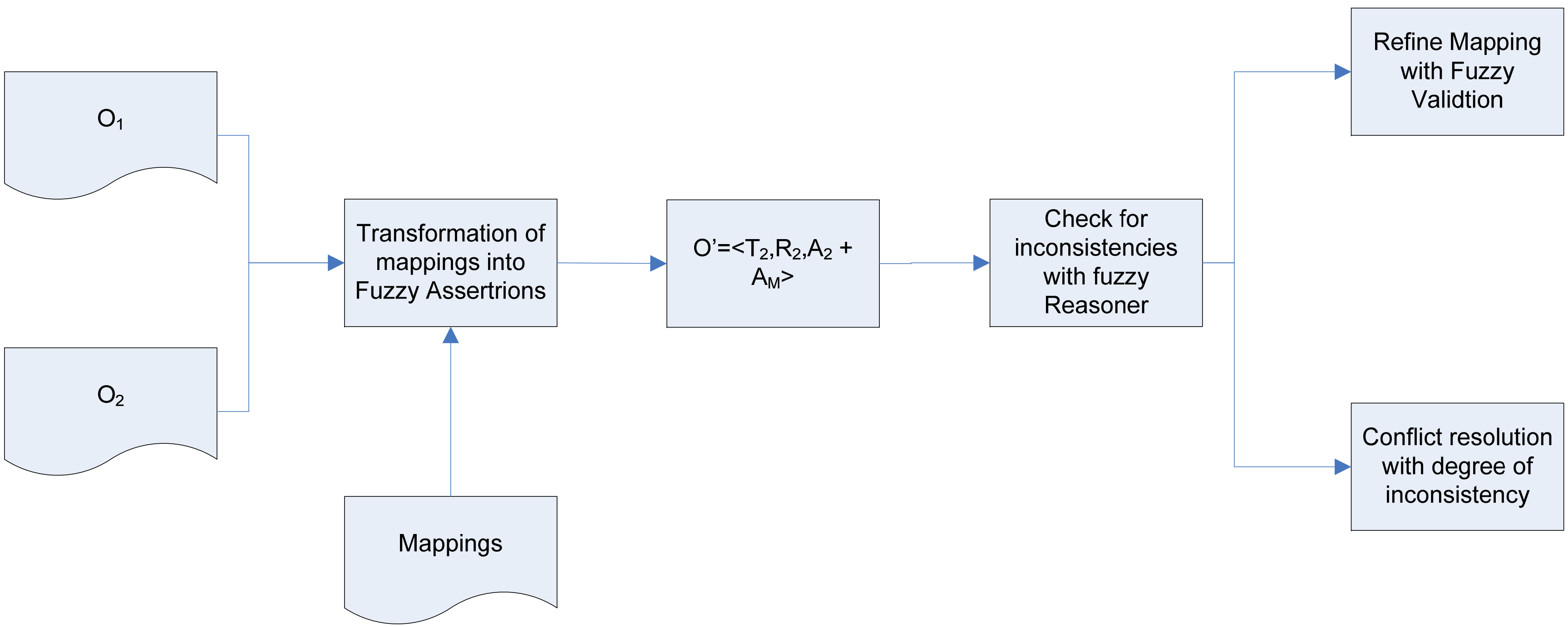
$$\mathcal{I} \models C \xrightarrow{\equiv} C' : n \iff \forall b. b \in C^{\mathcal{I}_c} \rightarrow C'^{\mathcal{I}}(b) = n$$

$$\mathcal{I} \models C \xrightarrow{\sqsubseteq} C' : n \iff \forall b. b \in C^{\mathcal{I}_c} \rightarrow C'^{\mathcal{I}}(b) \geq n$$

$$\mathcal{I} \models C \xrightarrow{\sqsupseteq} C' : n \iff \forall b. b \in C^{\mathcal{I}_c} \rightarrow C'^{\mathcal{I}}(b) \leq n$$

  - $MobileDevice \xrightarrow{\equiv} ElectronicDevice : 0.7 \iff md \in MobileDevice^{\mathcal{I}_c} \rightarrow ElectronicDevice^{\mathcal{I}}(md) = 0.7$
  - $MobileDevice \xrightarrow{\sqsubseteq} ElectronicDevice : 0.6 \iff md \in MobileDevice^{\mathcal{I}_c} \rightarrow ElectronicDevice^{\mathcal{I}}(md) \geq 0.6$
  - $MobileDevice \xrightarrow{\sqsupseteq} ElectronicDevice : 0.3 \iff md \in MobileDevice^{\mathcal{I}_c} \rightarrow ElectronicDevice^{\mathcal{I}}(md) \leq 0.3$

Validation Procedure using Fuzzy DLs

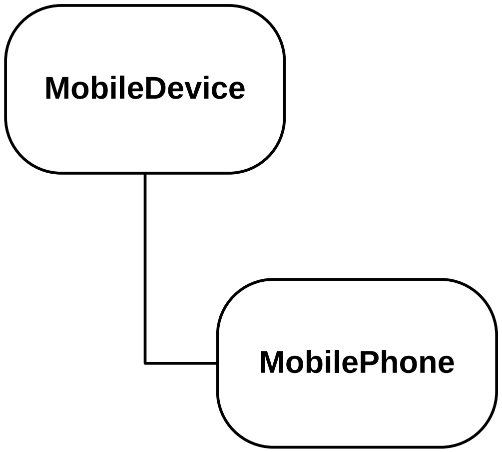


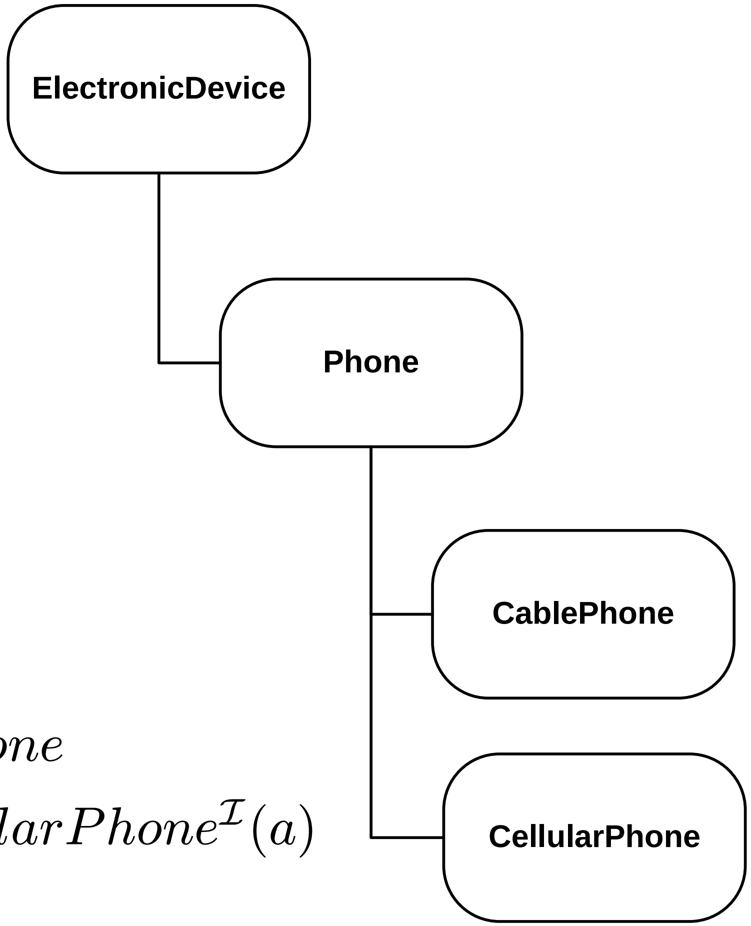
Refinement with Fuzzy Validation

- Starting from the strongest mapping to the weakest
- Use each mapping to transfer instances from O_1 to O_2.
- Inconsistency is checked every time a fuzzy assertion is created from the mappings
- Use low level information from the FiRE reasoner and refine the strength of the mapping

Example

1. map($MobileDevice$, $ElectronicDevice$, 0.7)
2. map($MobilePhone$, $Phone$, 0.6)
3. map($MobilePhone$, $CablePhone$, 0.4)
4. map($MobilePhone$, $CellularPhone$, 0.8)





$$MobilePhone(mp)$$

$$CablePhone \sqsubseteq \neg CellularPhone$$

$$CablePhone^{\mathcal{I}}(a) \leq 1 - CellularPhone^{\mathcal{I}}(a)$$

Example

1. $\text{map}(MobileDevice, ElectronicDevice, 0.7)$
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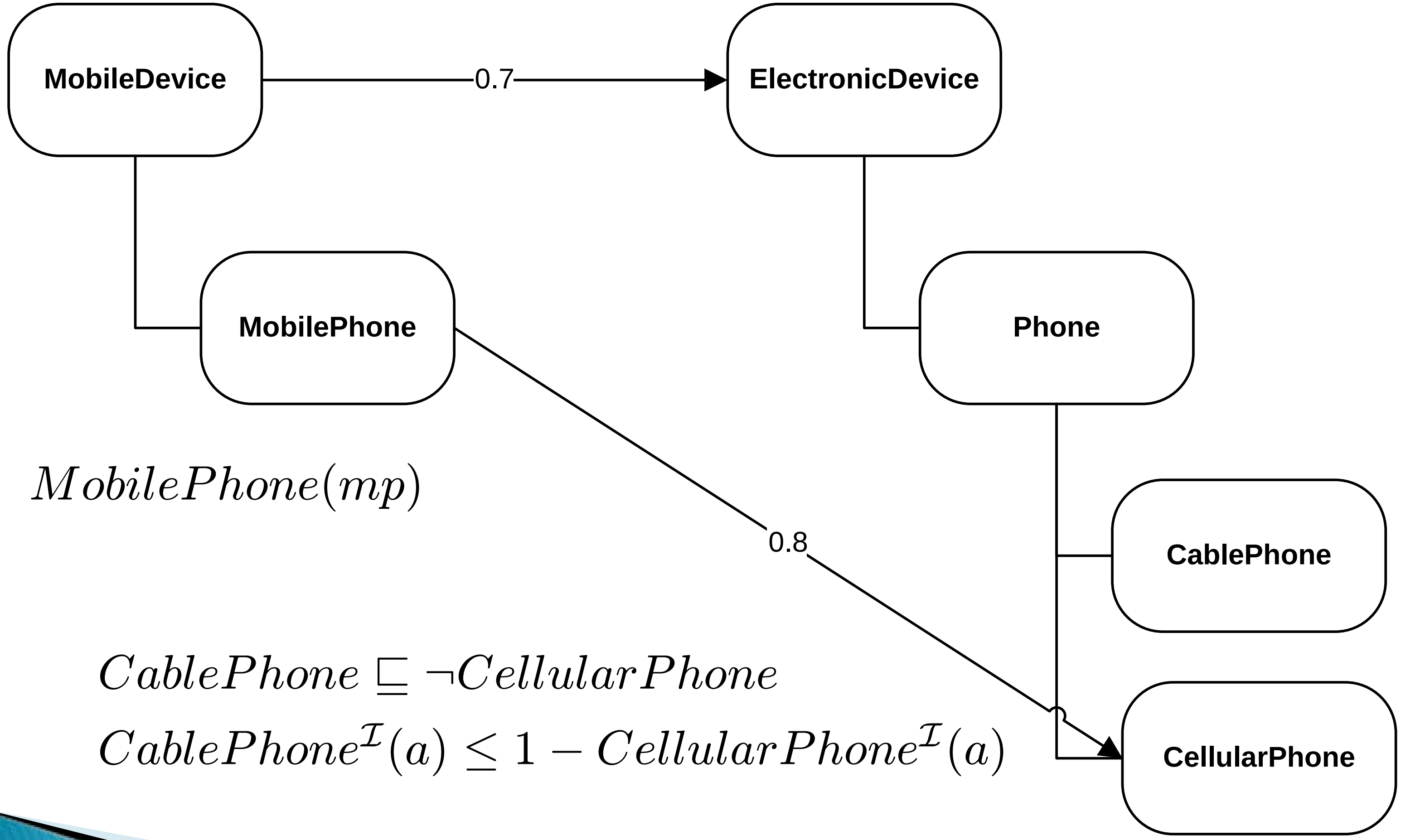

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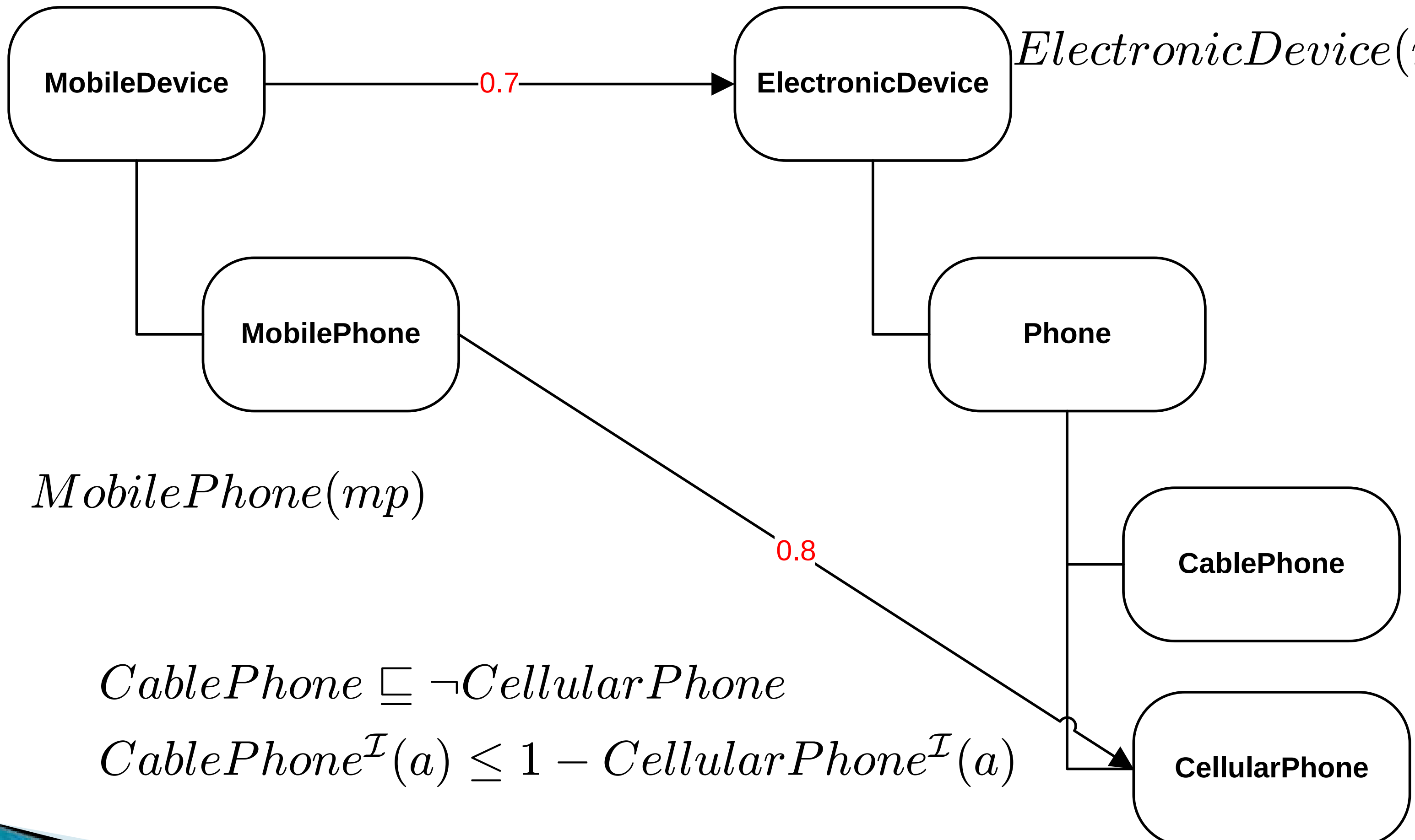

$$ElectronicDevice(mp) = 0.7$$

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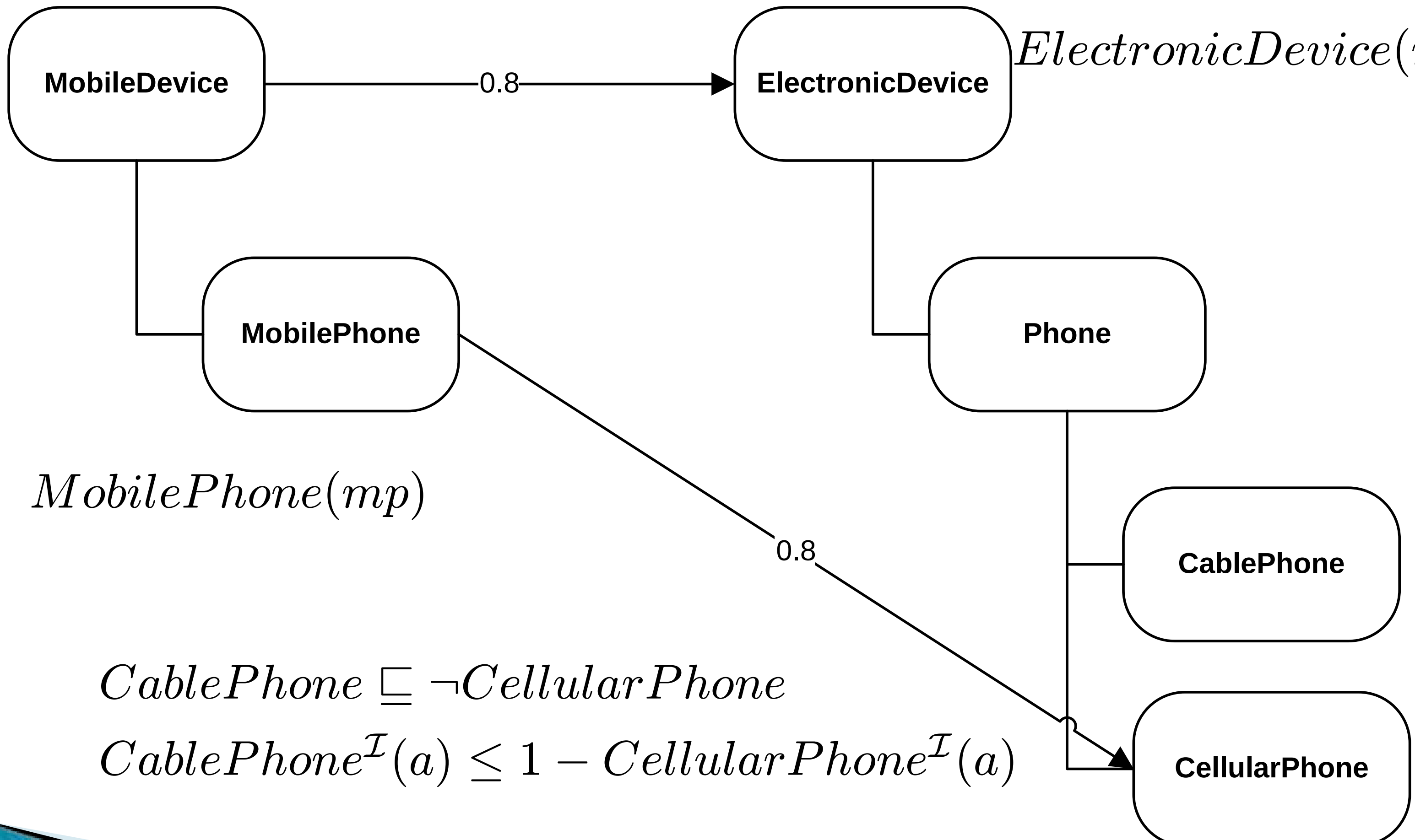

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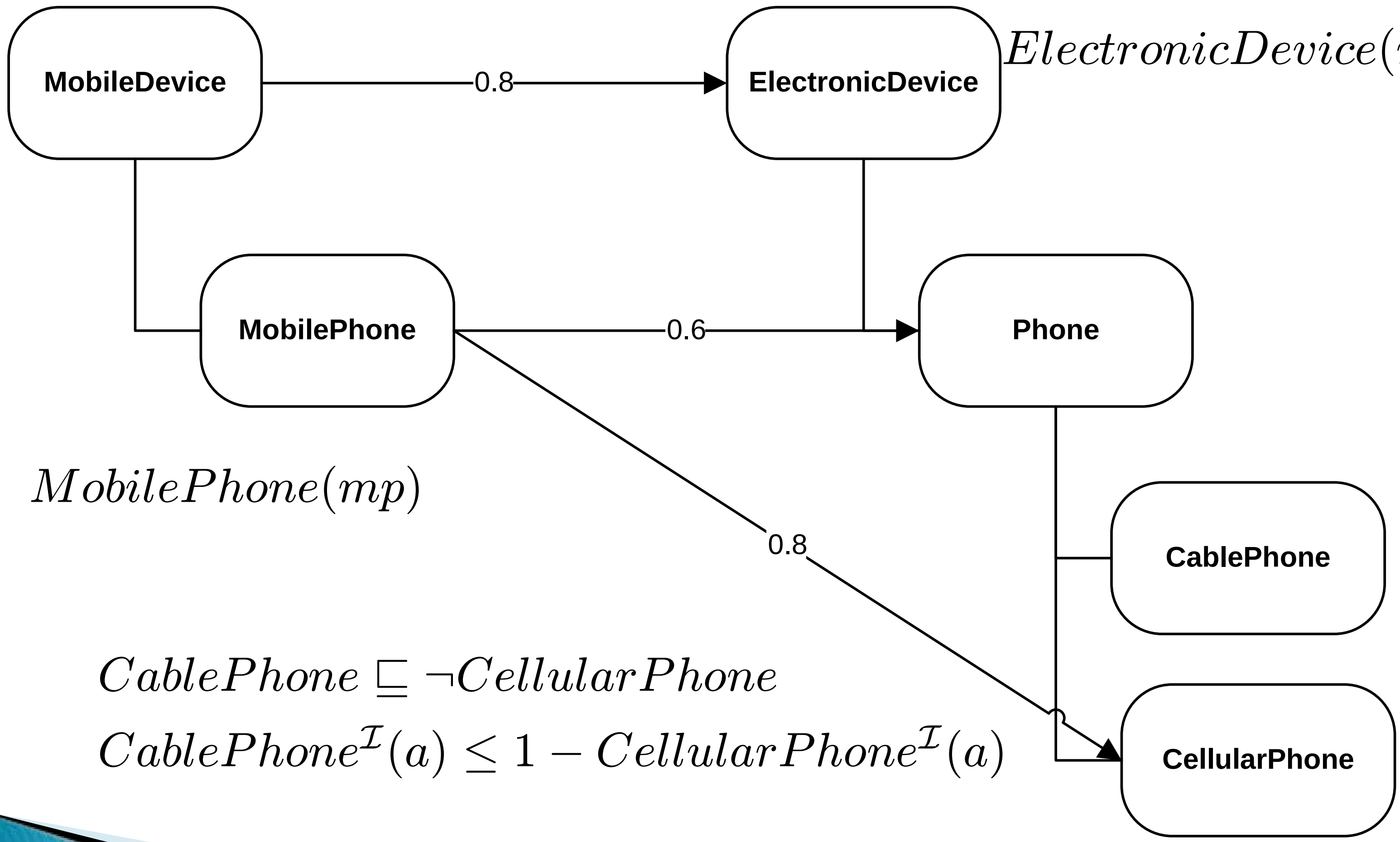

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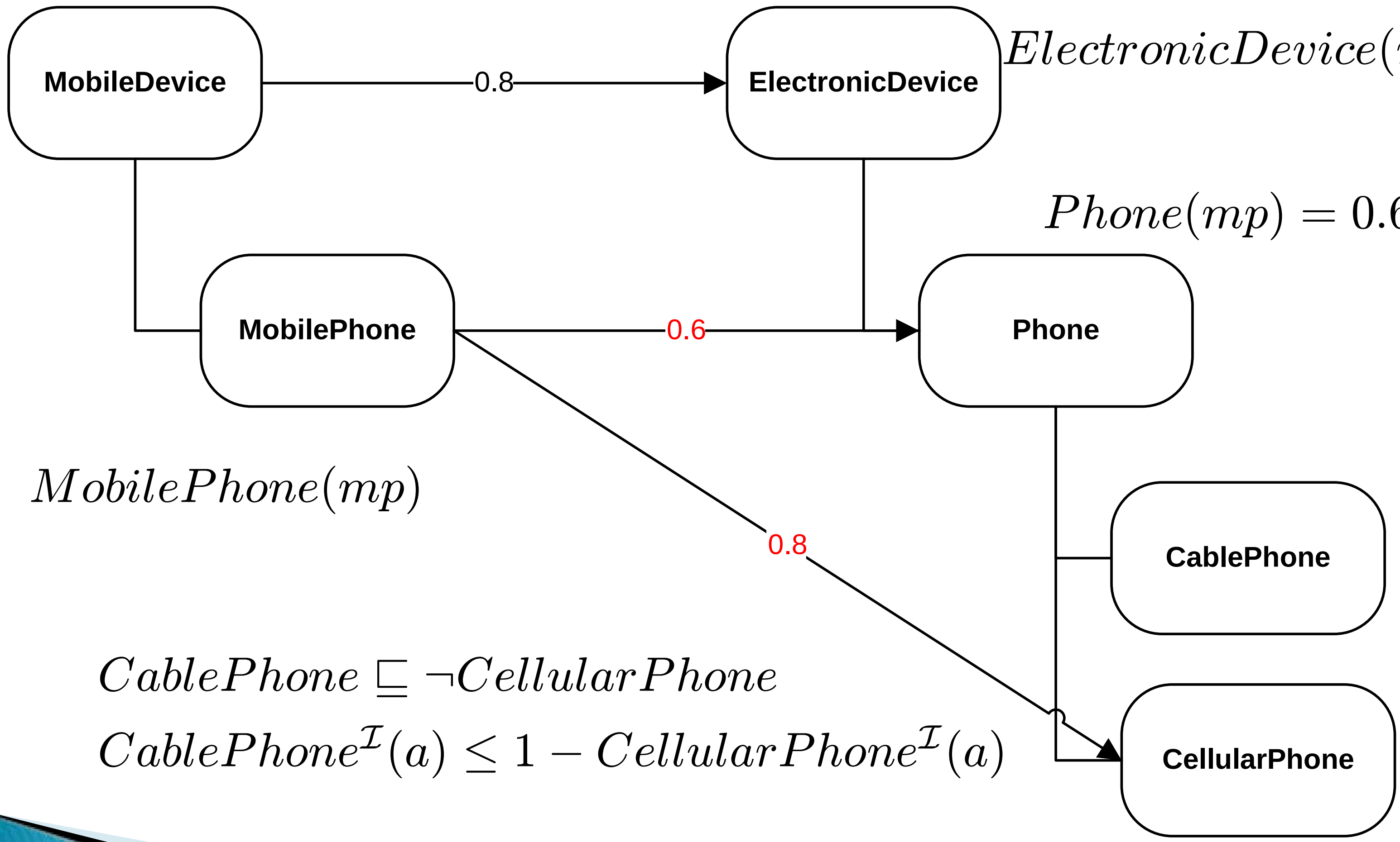

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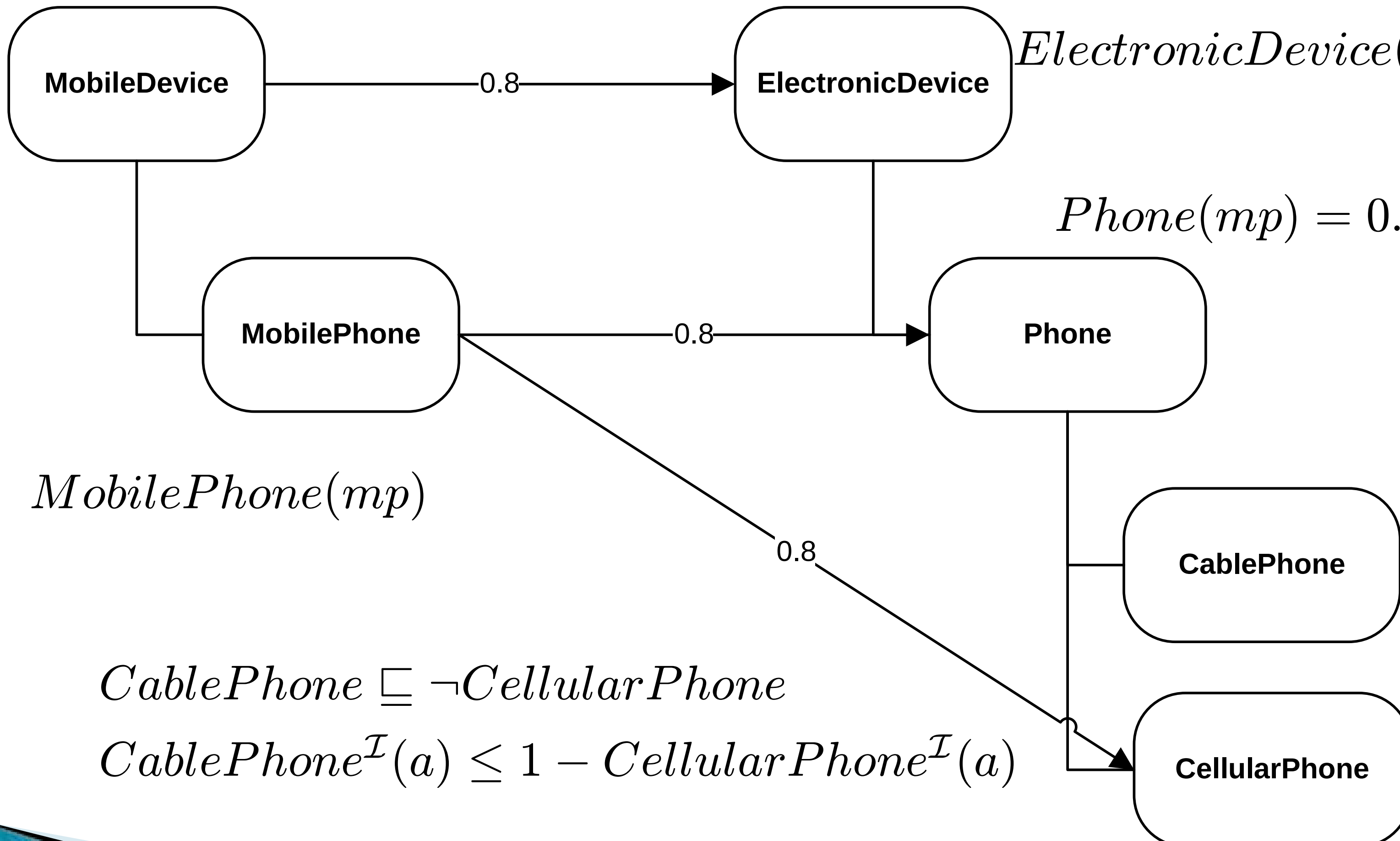

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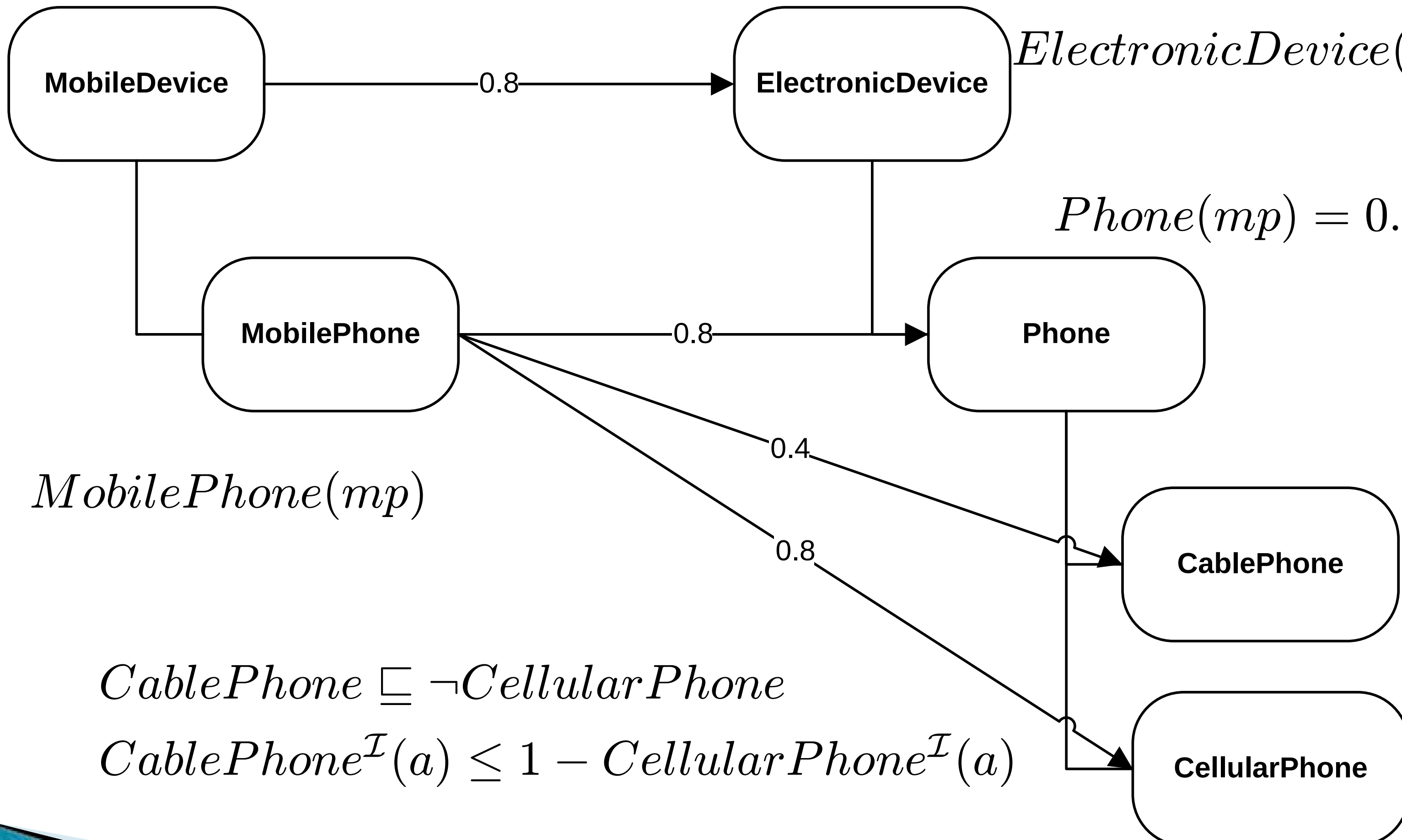

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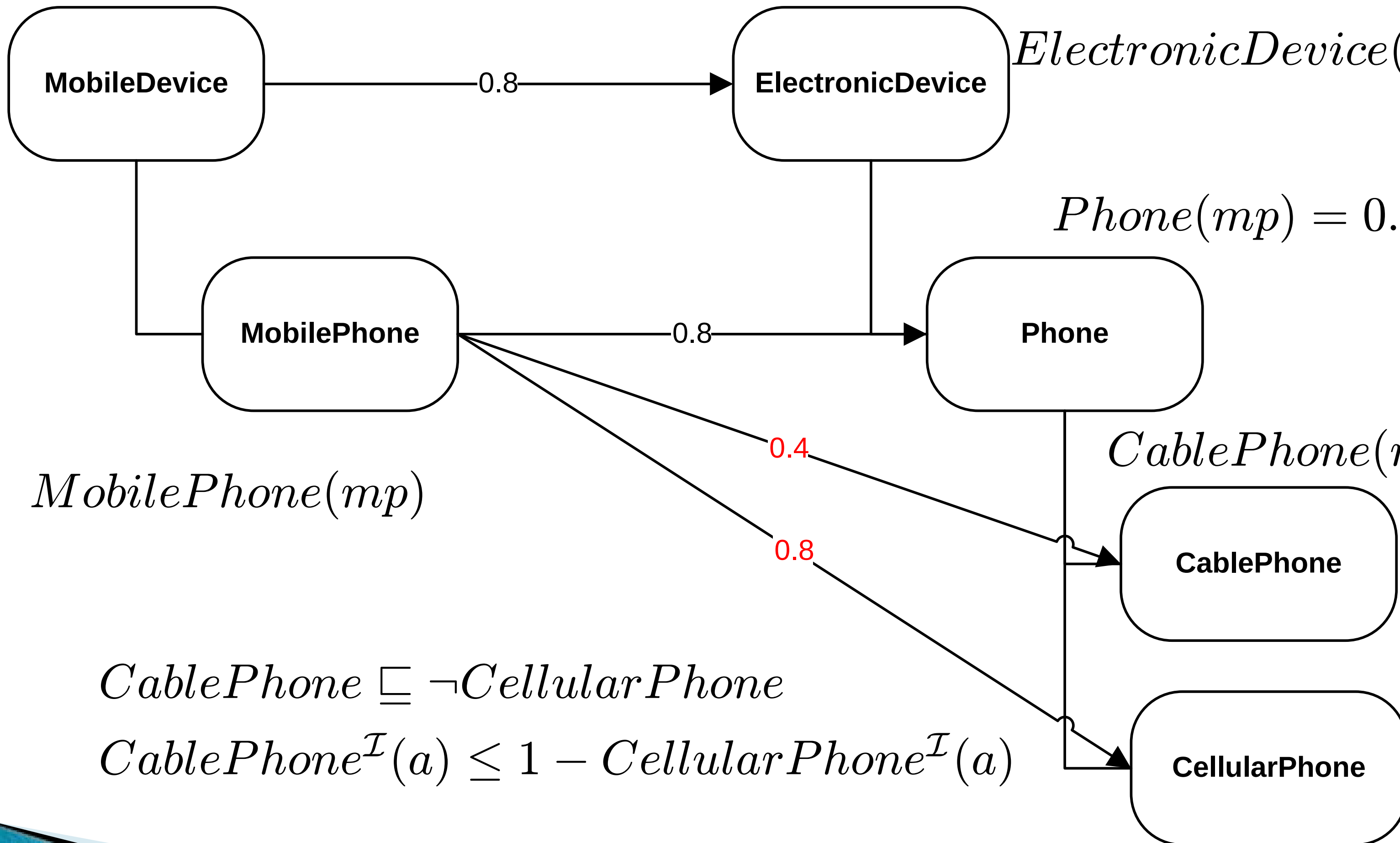

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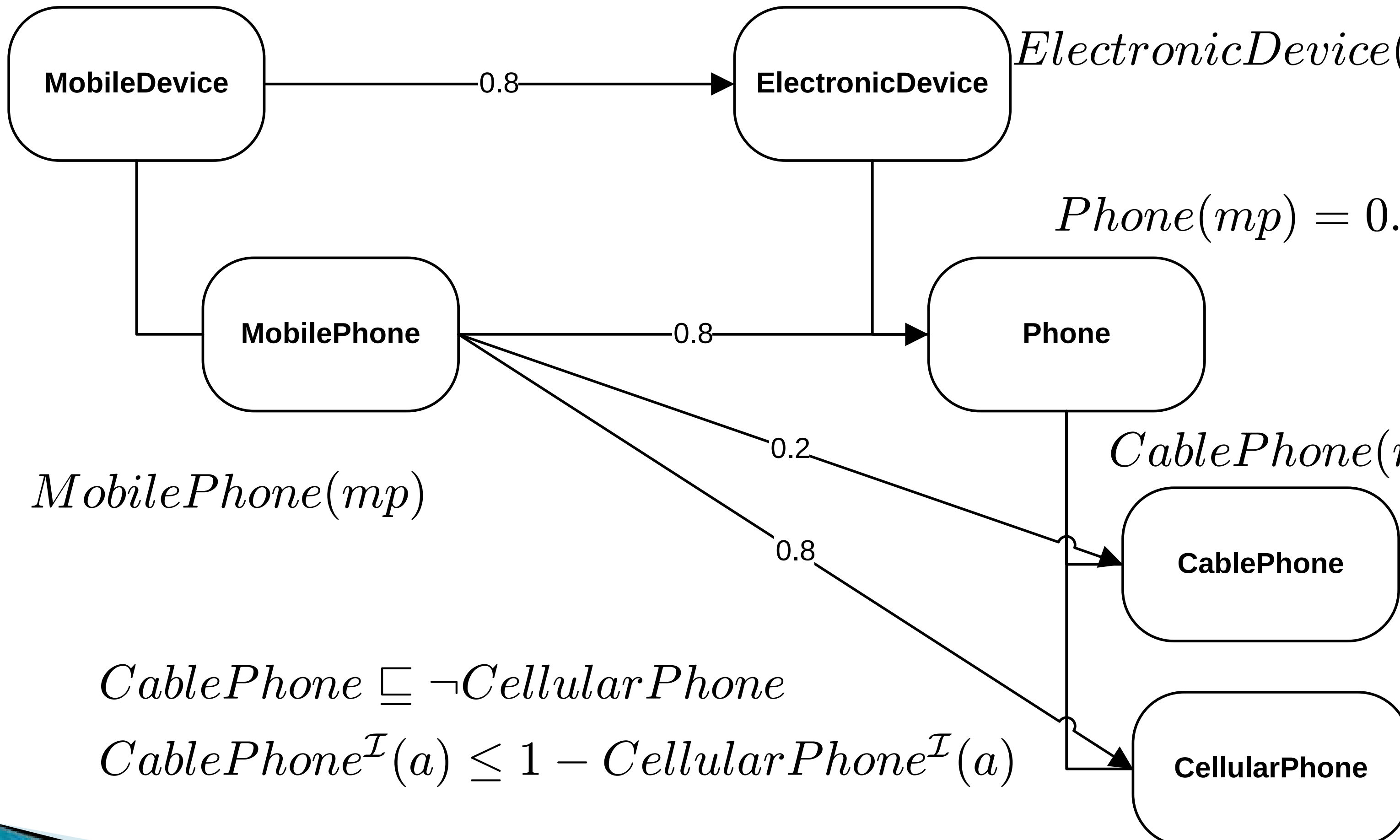

$ElectronicDevice(mp) = 0.8$

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$CellularPhone(mp) = 0.8$

Conflict Resolution with Degree of Inconsistency

- Number of times that a mapping is involved in a conflict
  - The higher the degree of inconsistency the more we benefit by removing it
- Inconsistency is checked only after all fuzzy assertions are created from the mappings
- Delete mappings that have the greater degree until consistency is achieved

Degree of Inconsistency

- Inconsistencies in all possible mapping configurations
  - $\overline{\mathcal{P}(M)} \equiv \mathcal{P}(M) \setminus \{x \in \mathcal{P}(M) \mid x = \emptyset \vee |x| = 1\}$
- Conflicting set
  - $\mathcal{C}(M) = \{c \in \overline{\mathcal{P}(M)} \mid \exists\ m, m' \in c \text{ and } m \text{ and } m' \text{ cause an inconsistency}\}$
- Minimal Conflicting set
  - $\mathcal{MC}(M) = \{mc \in \mathcal{C}(M) \mid \nexists\ mc' \in \mathcal{C}(M) \text{ such that } mc' \subseteq mc\}$
- Degree of Inconsistency
  - $i_m = |\{mc \in \mathcal{MC}(M) \mid m \in mc\}|$

Example

$$
\begin{array}{llll}
O_1: & MobilePhone & \sqsubseteq & MobileDevice \\
O_2: & Phone & \sqsubseteq & ElectronicDevice \\
 & CablePhone & \sqsubseteq & Phone \\
 & CellularPhone & \sqsubseteq & Phone \\
 & CablePhone & \sqsubseteq & \neg CellularPhone
\end{array}
$$

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- $\overline{\mathcal{P}(M)} = \{(1,2),(1,3),(1,4),(2,3),(2,4),(3,4),(1,2,3),(1,2,4),\ldots\}$
- $\mathcal{C}(M) = \{(1,2),(1,3),(3,4),(1,2,3),(1,2,4),(2,3,4),(1,2,4),(1,2,3,4)\}$
- $\mathcal{MC}(M) = \{(1,2),(1,3)(3,4)\}$
- $i_1 = |\{(1,2),(1,3)\}| = 2, \quad i_2 = |\{(1,2)\}| = 1, \quad i_3 = 2, \quad i_4 = 1$
- All mappings are added into the resulting ontology and mappings 1 and 3 are removed so as to restore consistency

Conclusion

- We have presented two methods of conflict resolution based on Fuzzy Description Logic theories
  - Conflicting mapping with the highest degree is preserved
  - Minimal set of consistent mappings are preserved
- Future Work
  - Evaluation
  - Exploring other strategies

Thank You!