Computational Model of Grounding
David Traum 1994, 1999

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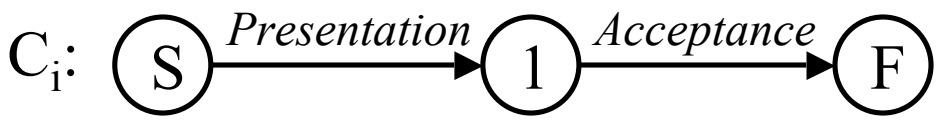
Grounding States in Clark's Contribution Model

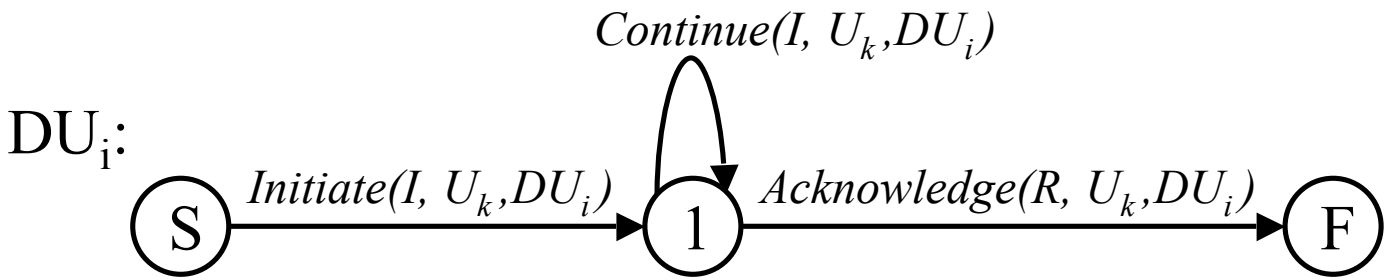
- What state is a contribution C_i in?



- What is the function of utterance U_k?
  - Is U_k acceptance-phase of C_i or presentation-phase of C_{i+1}?

Grounding Acts in Traum's Model

- What is the function of utterance U_k?
  - Does U_k initiate, continue of complete a discourse unit DU_i?



Discourse unit (DU_i): unit of (to be) grounded content

Examples of Grounding Acts in Traum's Model

(1)	1:A: Move the boxcar to Corning	Init(A,1,DU1)
	2:A: and load it with oranges	Cont(A,2,DU1)
	3:B: OK	Ack(B,3,DU1)
(2)	1:A: Move the boxcar to Corning	Init(A,1,DU1)
	2:B: OK	Ack(B,2,DU1)
	3:A: and load it with oranges	Init(A,3,DU2)
	4:B: OK	Ack(B,4,DU2)

(see Traum 1998)

What's a Discourse Unit?

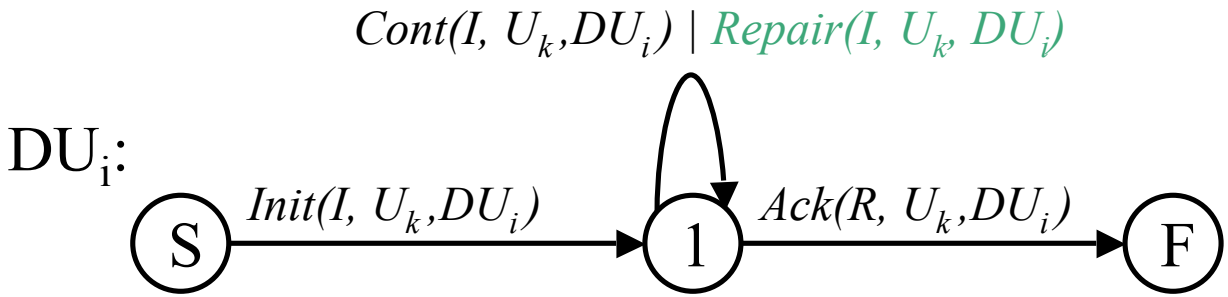
(1)	1:A: Move the boxcar to Corning 2:A: and load it with oranges 3:B: OK	Init(A,1,DU1) Cont(A,2,DU1) Ack(B,3,DU1)
(1')	1:A: Move the boxcar to Corning 2:A: and load it with oranges 3:B: OK	Init(A,1,DU1) Init(A,3,DU2) Ack(B,4,DU1+DU2)
(2')	1:A: Move the boxcar to Corning 2:B: OK 3:A: and load it with oranges 4:B: OK	Init(A,1,DU1) Ack(B,2,DU1) Init(A,3,DU2) Ack(B,4,DU2)

What's a Discourse Unit?

(1)	1:A: Move the boxcar to Corning	Init(A,1,DU1)
	2:A: and load it with oranges	Cont(A,2,DU1)
	3:B: OK	Ack (B,3,DU1)
(2')	1:A: Move the boxcar to Corning	Init(A,1,DU1)
	2:B: OK	Ack (B,2,DU1)
	3:A: and load it with oranges	Cont(A,3,DU1)
	4:B: OK	Ack (B,4,DU1)

Adding Self-Repair

- Self-repair (of DU_i by I):



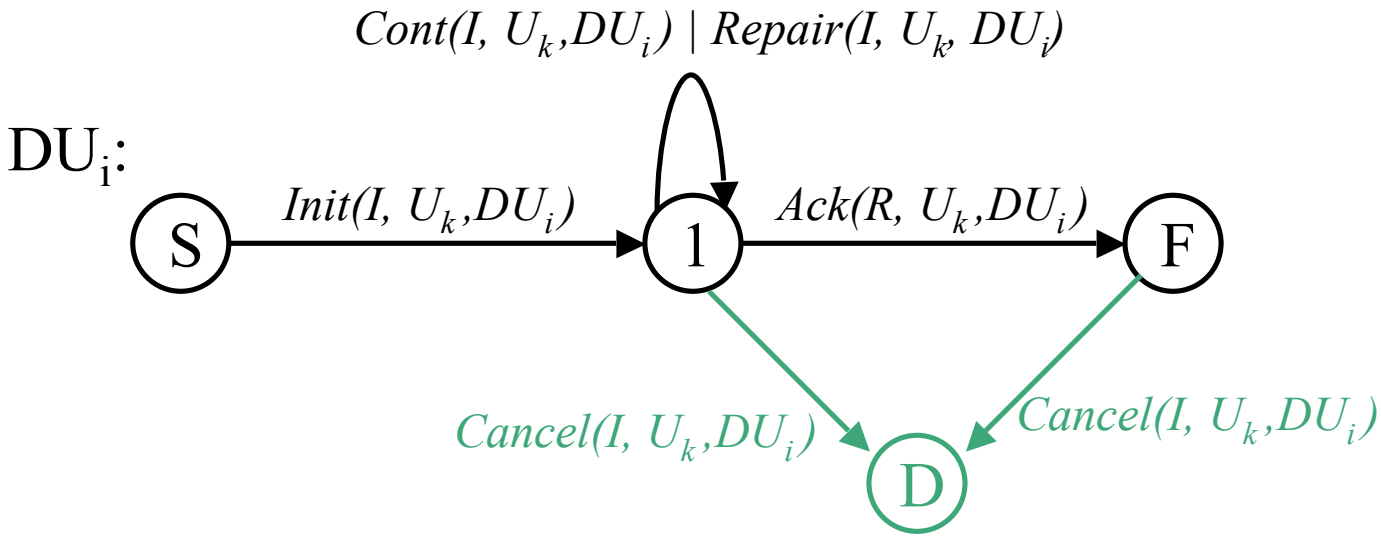
Self-Repair Example

(3) 1:A: Move the boxcar to Bath
2:A: I mean, Corning
3:B: OK

Init(A,1,DU1)
Repair(A,2,DU1)
Ack(B,3,DU1)

Adding Cancelation

- Abandoning of DU_i by I:

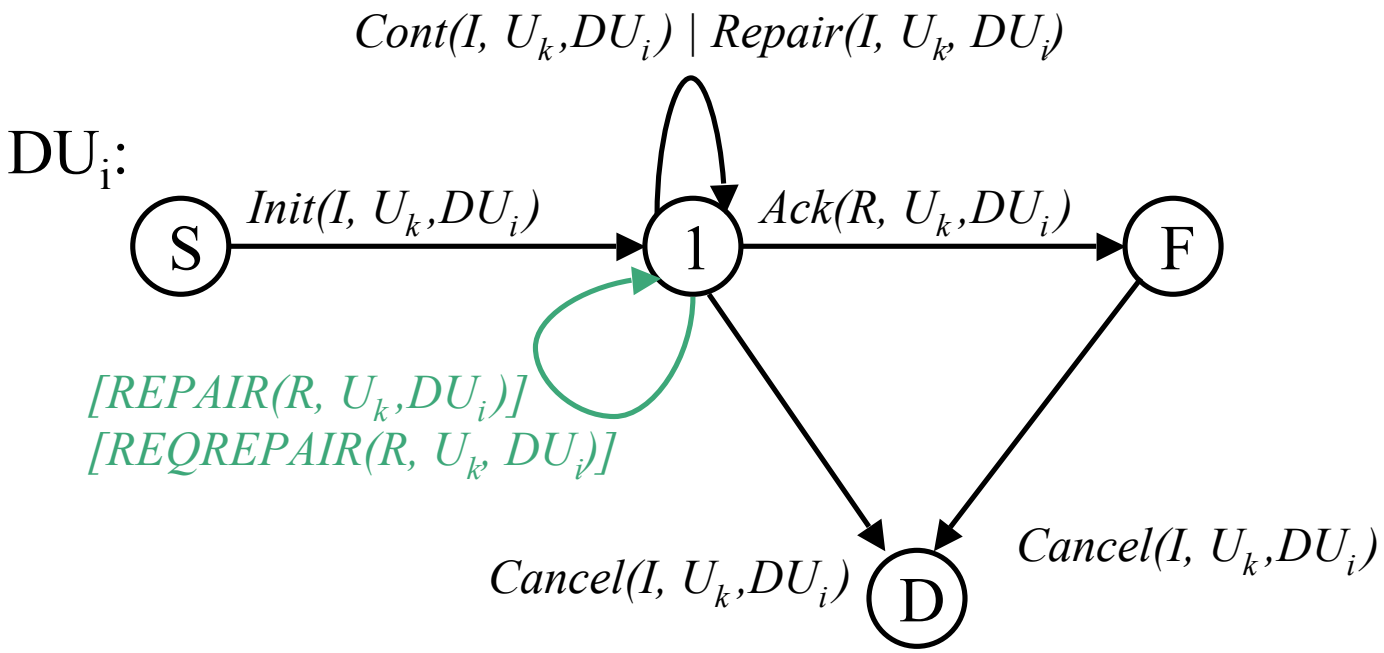


Cancelation Example

(3) 1:A: Move the boxcar to Bath	Init(A,1,DU1)
2:A: and load it with oranges	Cont(A,2,DU1)
3:B: OK	Ack (B,3,DU1)
4:A: Eh, no, forget that.	Canc(A,4,DU1)
5:A: Move the boxcar to Corning	Init(A,5,DU2)
....	

Adding Other-Repair

- Other-repair and repair-request (of DU_i by R):

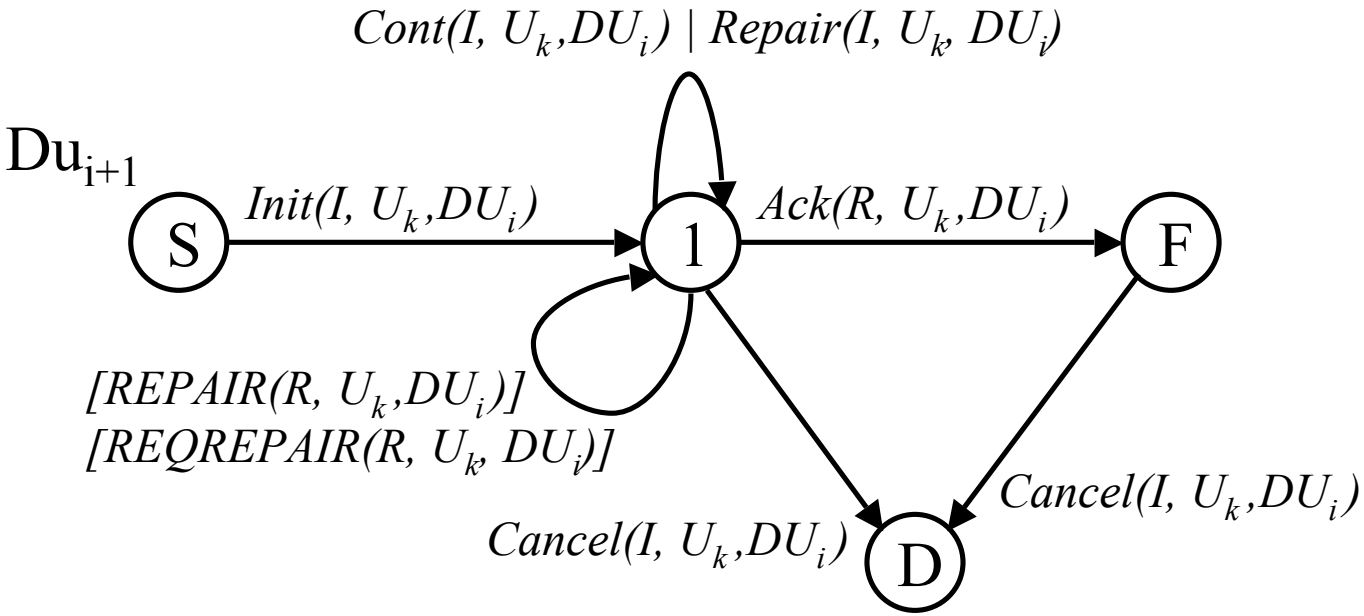


Other-Repair Example

(4) 1:A: Move the boxcar to Bath	Init(A,1,DU1)
2:B: To Corning	Repair(B,2,DU1)
	≈ Init(B,2,DU2)
3:A: Oh, sure.	Ack (A,3,DU2)
(5) 1:A: Move the boxcar to Bath	Init(A,1,DU1)
2:B: Bath?	ReqRepr(B,2,DU1)
	≈ Init(B,2,DU2)
3:A: Oh, Corning.	Ack(A,3,DU2)
	Repair(A,3,DU1)
4:B: OK	Ack (R,4,DU1)

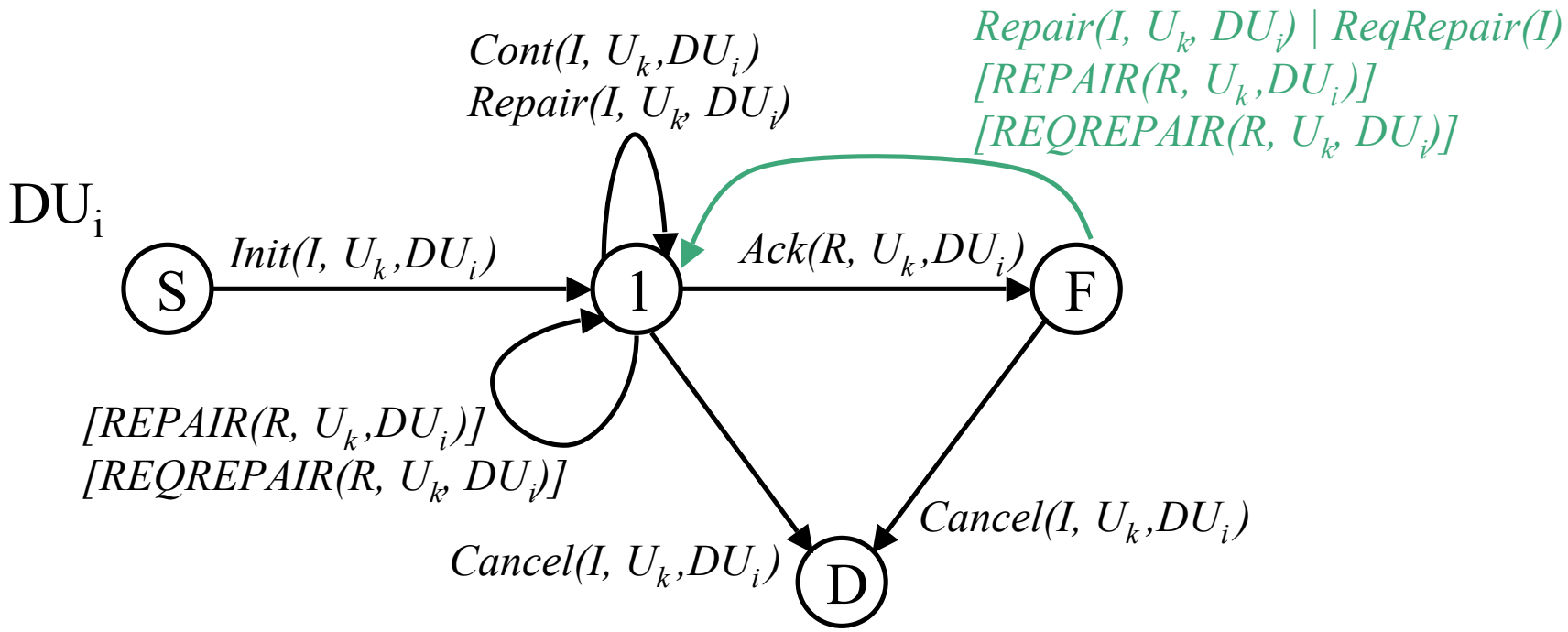
Recursive Embedding

- Other-repair is itself an embedded DU_{i+1}
  - $Repair(R,U_k,DU_i) \approx Init(I,U_k,DU_{i+1})$
  - $ReqRepair(R,U_k,DU_i) \approx Init(I,U_k,DU_{i+1})$



More Repair (Requests)

- Other-repair and repair-request (of DU_i by I/R):

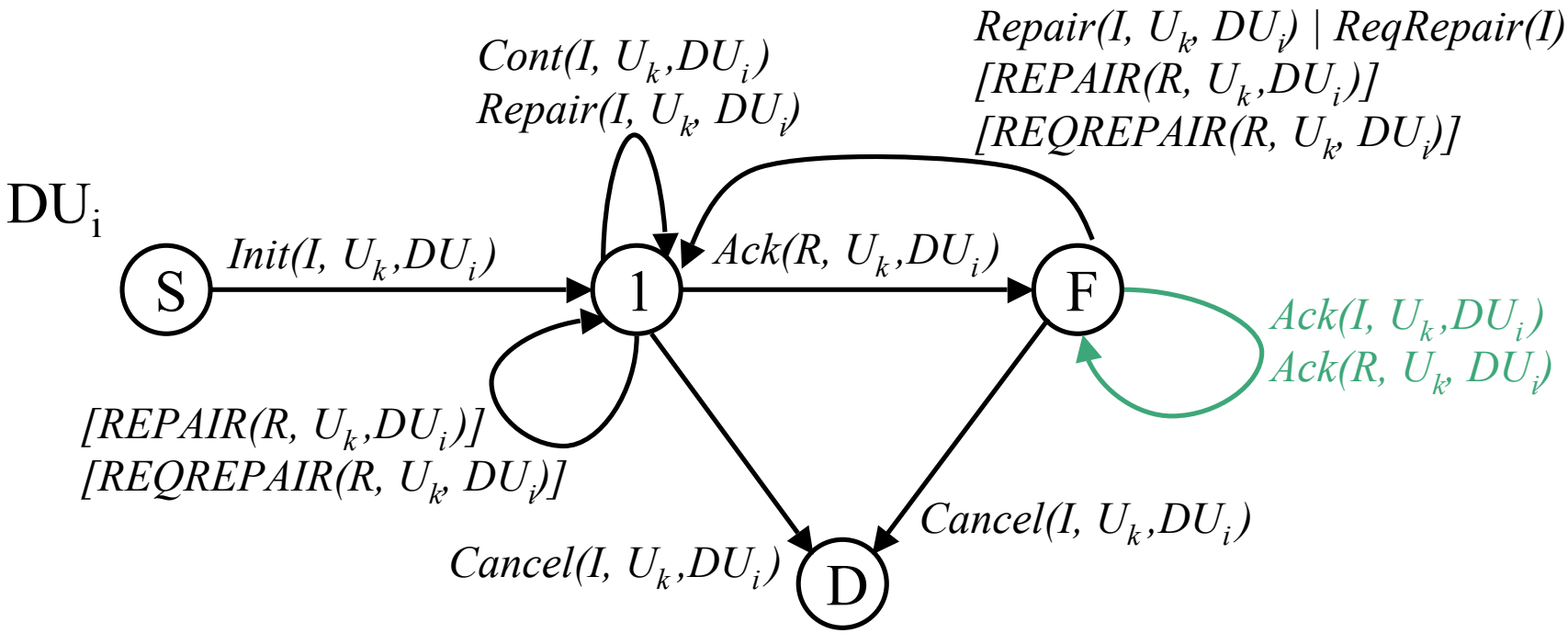


Other-Repair (Request) Example

(6) 1:A: Move the boxcar to Corning	Init(A,1,DU1)
2:A: and load it with pineapples	Cont(A,2,DU1)
3:B: OK	Ack (B,3,DU1)
4:A: I mean, oranges.	Repair(A,4,DU1)
5:A: OK.	Ack(B,5,DU1)
(7) 1:A: Move the boxcar to Corning	Init(A,1,DU1)
2:A: and load it with pineapples	Cont(A,2,DU1)
3:B: OK.	Ack (B,3,DU1)
4:B: Pineapples?	ReqRepr(B,4,DU1)
5:A: I mean, oranges.	Repair(A,5,DU1)
6:B: OK.	Ack(B,6,DU1)

More Acknowledgements

- Acknowledgements of completed DU_i by I or R

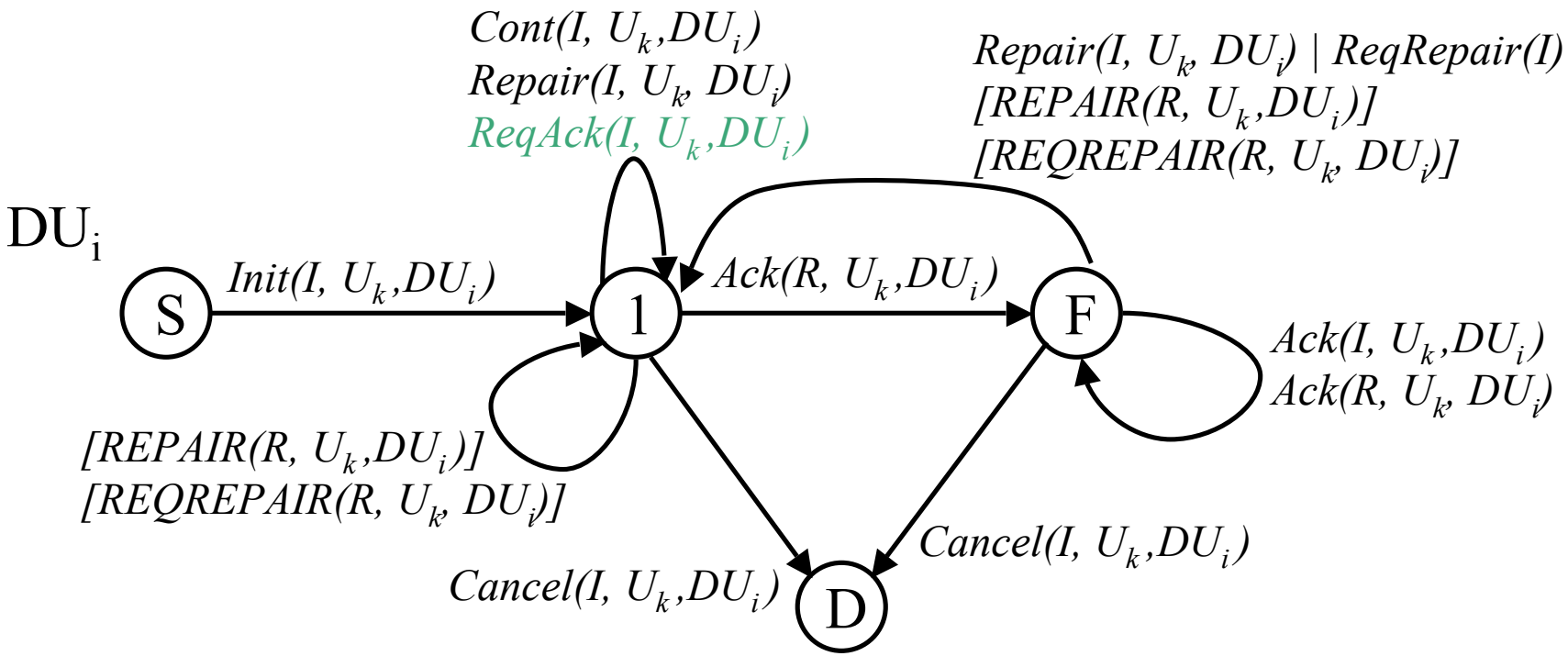


Acknowledgements Example

(8)	1:A: Move the boxcar to Corning	Init(A,1,DU1)
	2:A: and load it with oranges	Cont(A,2,DU1)
	3:B: OK	Ack(B,3,DU1)
	4:B: To Corning, load with oranges.	Ack(B,4,DU1)
	4:A: OK	Ack(A,5,DU1)

Acknowledgement Requests

- Acknowledgement request by I



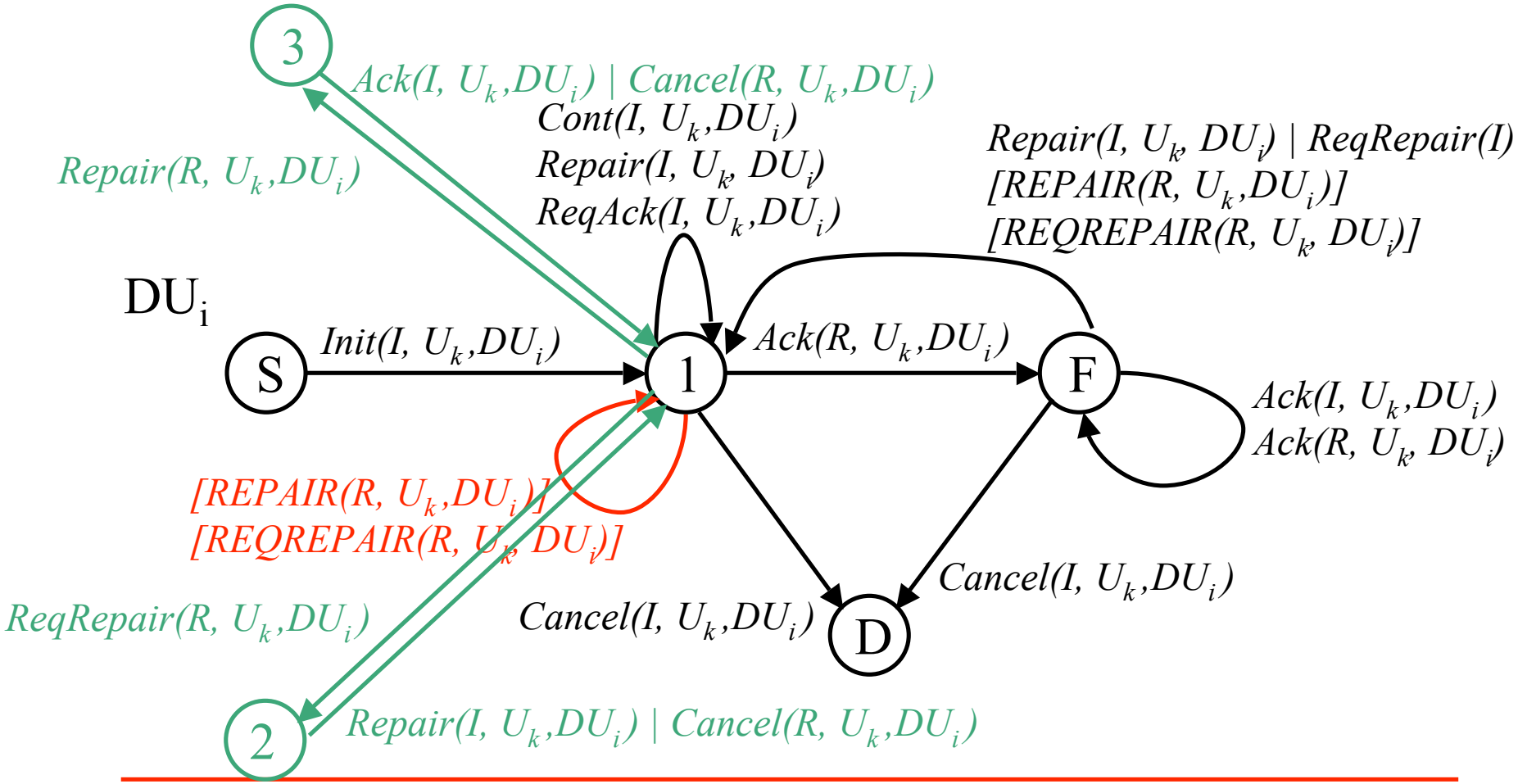
Acknowledgement Request Example

(8)	1:A: Move the boxcar to Corning	Init(A,1,DU1)
	2:A: and load it with oranges	Cont(A,2,DU1)
	3:A: OK?	Ack(B,3,DU1)
	4:B: Corning, oranges.	Ack(B,4,DU1)
	5:A: Yes	Ack(A,5,DU1)
	6:B: OK.	Ack(B,6,DU1)

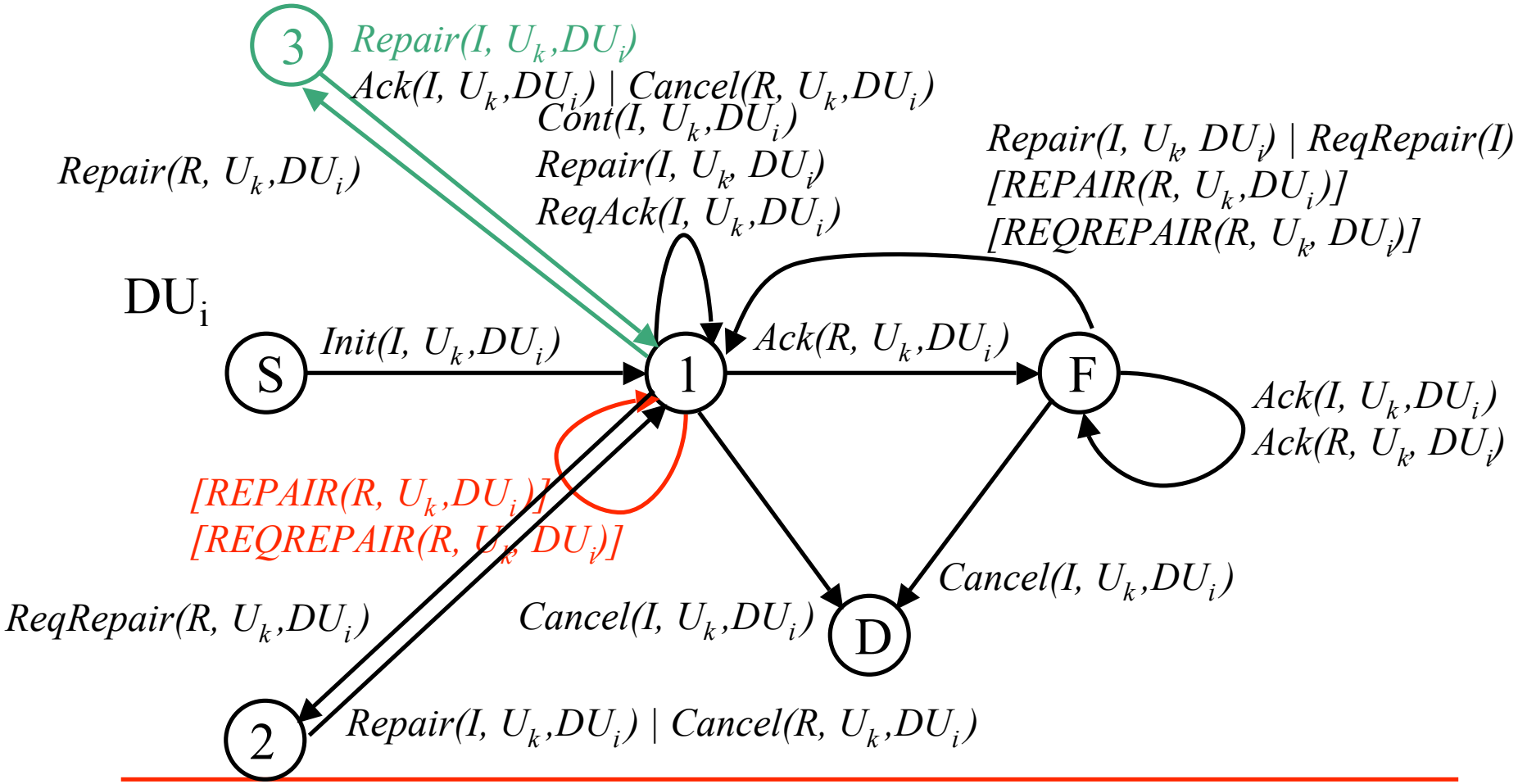
Is Recursion Necessary?

- Recursion adds computational complexity and is expensive
- Unlimited recursion depth is psychologically unlikely
- Pushdown storage → finite model

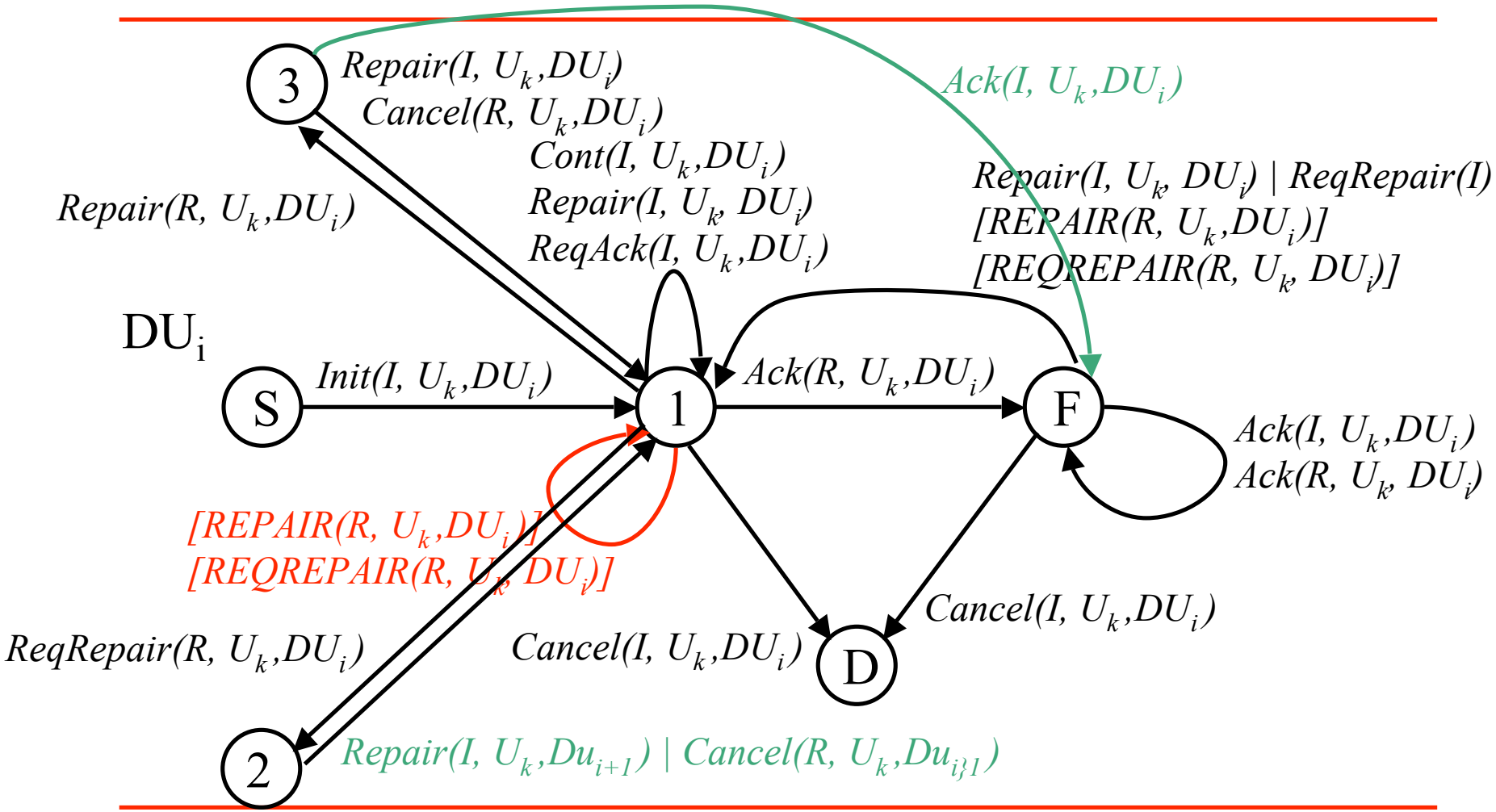
Finite Model (1)



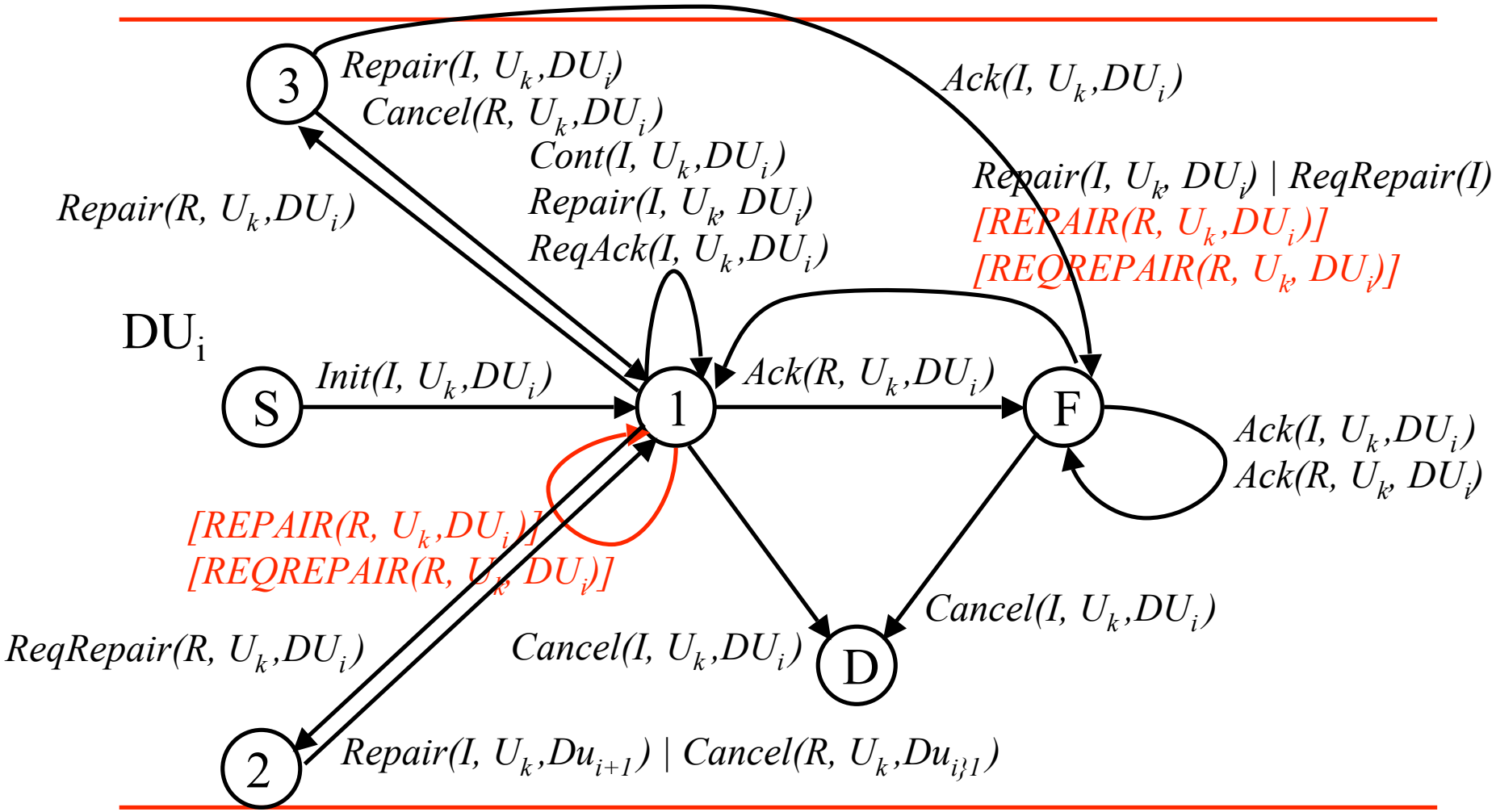
Finite Model (2)



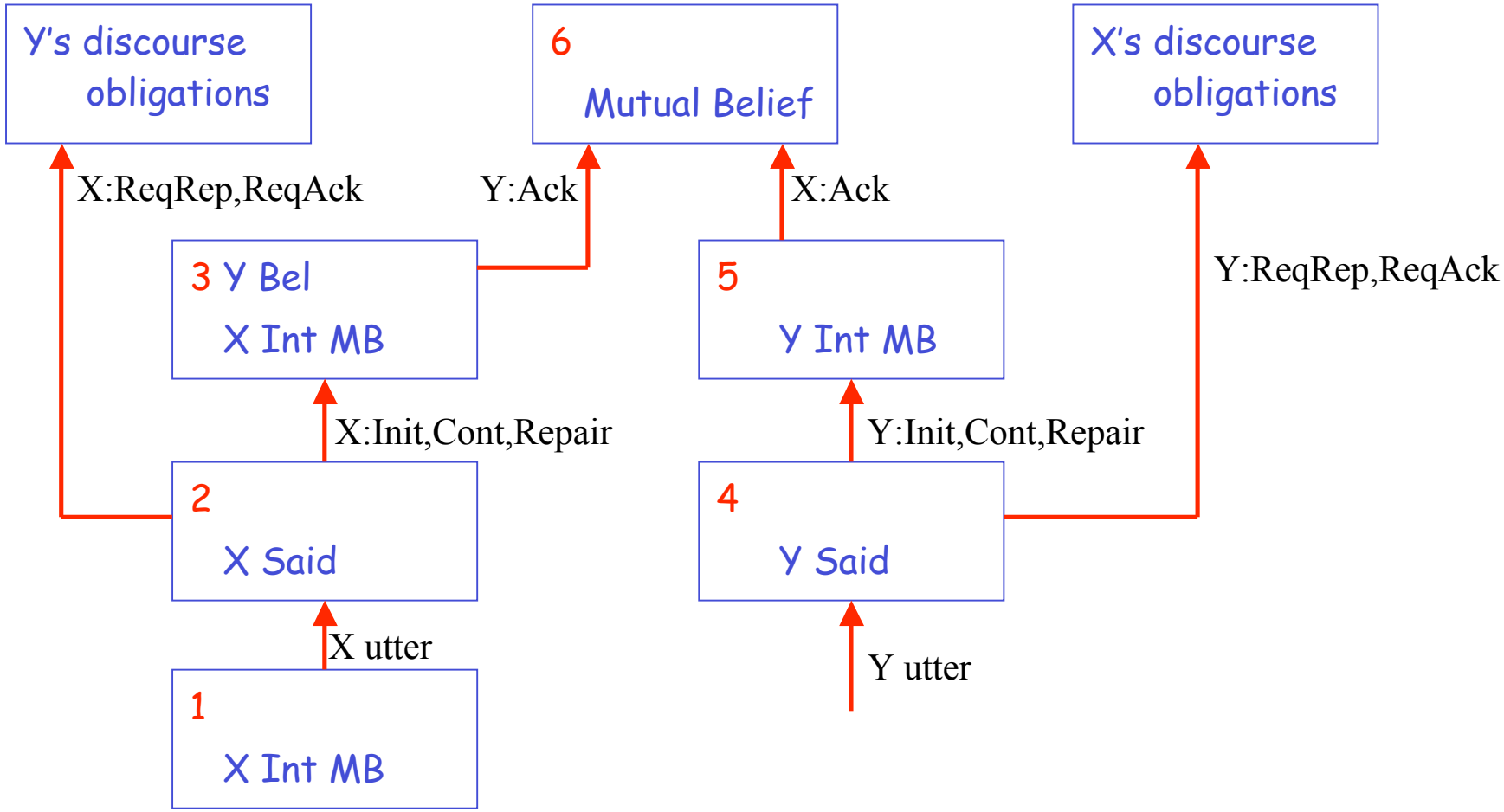
Finite Model (3)



Finite Model (4)



Cognitive Model of Grounding Act Processing



Issues / Deficiencies

- Degrees of groundedness just binary
  - But there is evidence of graded groundedness
- Utterance unit size (cf. Ex.1)
  - Problem for coding, but any practical solution goes
- Discourse unit size
  - Center embedding (cf. Ex.1,1',2,2')
  - Partial acknowledgement (cf. Ex.7)
- Grounding act ambiguity/unspecificity
  - Entertain multiple possibilities, eliminate later ?
  - Best-first strategy with revision/backtracking ?
- Extension to multimodal or embodied interaction?

Graded Groundedness

Types of evidence of understanding

1. Verbatim display
2. Demonstration
3. Acknowledgement
4. Initiation of relevant next contribution
5. Continued attention

[Clark&Schaefer 1989, Clark 1996]