From Partial to Global Asynchronous Reliable Broadcast

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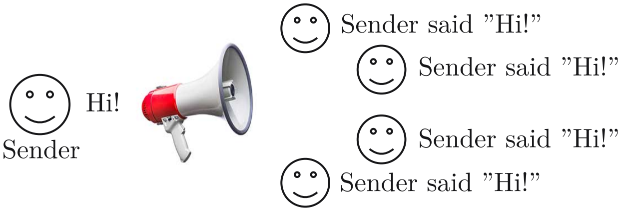
DISC 2020

Broadcast

Broadcast allows a party to consistently distribute a message to n recipients.



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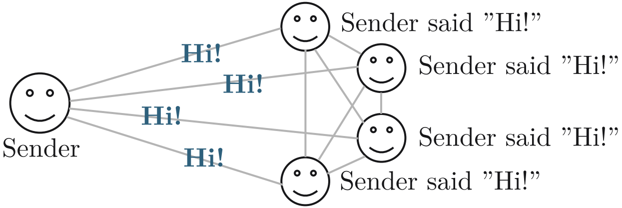

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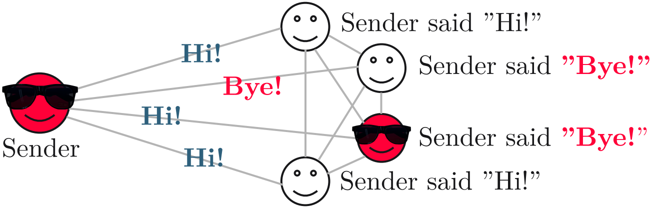

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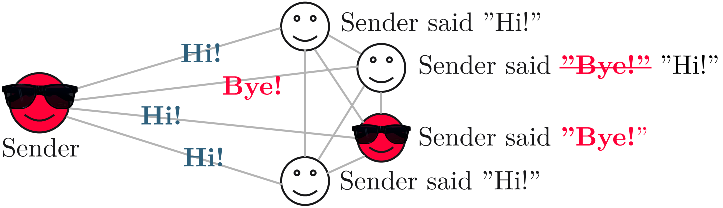

(Consistency)

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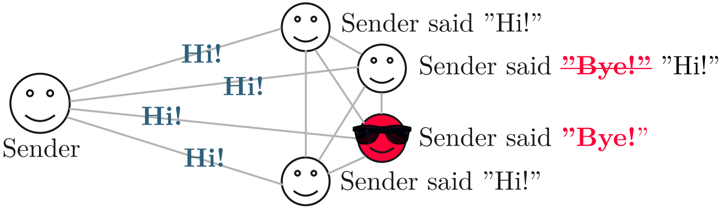
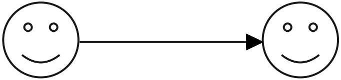


(Validity)

Model

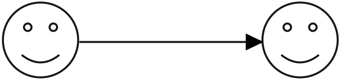
Synchronous channels



I will receive the
message in one hour.

Model

Asynchronous channels



I will receive the message **eventually**. **If it was sent.**

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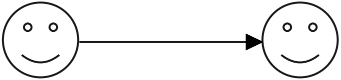

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If it was sent.

Adversary

- Controls the delay time of the messages.
- Corrupts up to t parties: they send wrong messages or they do not send some of the messages.

Achieving Asynchronous Reliable Broadcast

To achieve asynchronous reliable broadcast, a protocol must satisfy the following properties:

Validity

Honest Sender with input m

$\implies$ Every honest recipient terminates and outputs m.

Consistency

An honest recipient terminates with output m

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Thresholds

	Synchronous BC	Asynchronous RBC
Traditional model	$t < n/3$ [PSL80]	$t < n/3$ [BraTou85]
PKI		
b-cast		

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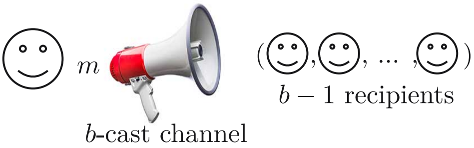

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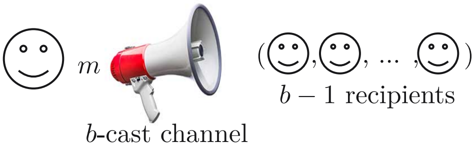

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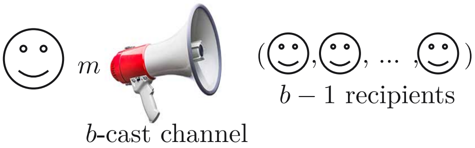

Our Results

Feasibility

Impossibility

In the asynchronous setting, there is no protocol achieving ( ) reliable broadcast secure against $t \geq \frac{b-1}{b+1}n$ corruptions.

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- An asynchronous reliable broadcast protocol for $b = 3$, secure against $t < n/2$ corruptions.

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- An asynchronous reliable broadcast protocol, secure against $t < \frac{b-4}{b-2}n$ corruptions.

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Our Results

Feasibility

- An asynchronous reliable broadcast protocol for $b = 3$, secure against $t < n/2$ corruptions.
- An asynchronous reliable broadcast protocol, secure against $t < \frac{b-4}{b-2}n$ corruptions.
- A *nonstop* reliable broadcast protocol, secure against $t < \frac{b-1}{b+1}n$ corruptions.

Impossibility

In the asynchronous setting, there is no protocol achieving (*nonstop*) reliable broadcast secure against $t \geq \frac{b-1}{b+1}n$ corruptions.

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$(R, \star)$  m 

P

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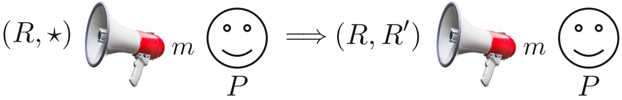

Protocol in $\mathcal{N}_3$

Code for Sender S

1. On input m:
   mega-send $(\texttt{MSG}, \mathbf{m})$

S

$(\texttt{MSG}, m)$

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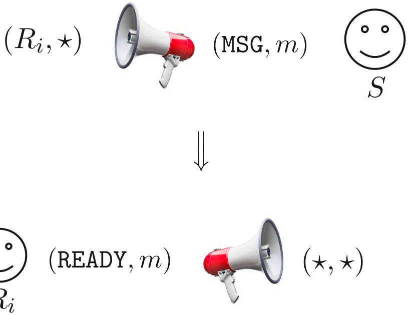

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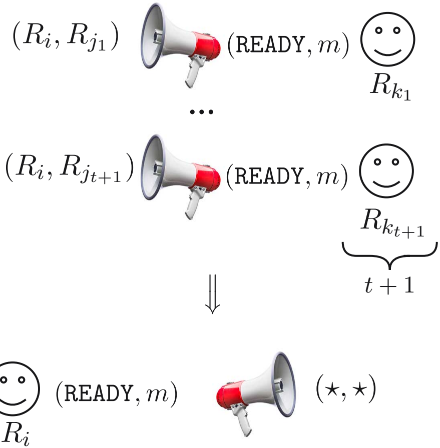

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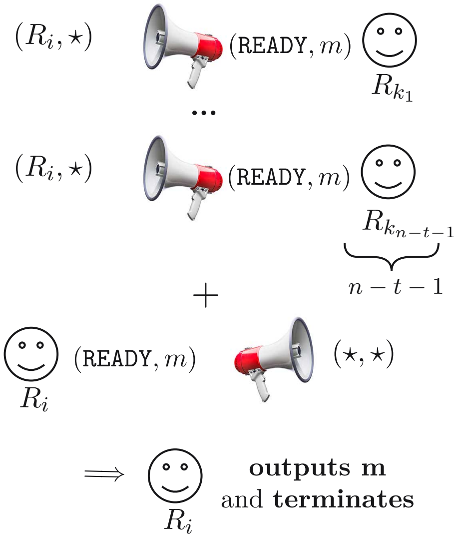
   output m and **terminate**



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Honest Sender's input: m

Fact:
Honest R cannot mega-send $(\texttt{READY}, m')$

$\implies$ R mega-sends $(\texttt{READY}, m)$

$\implies$ R **outputs** m

Consistency: $t < n - t$

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Fact #1:
An honest R mega-sends $(\texttt{READY}, m)$
$\Longrightarrow$ No honest R' mega-sends $(\texttt{READY}, m')$

$\Longrightarrow$ **No honest R' outputs m'**

Fact #2:
An honest R outputs m
$\Longrightarrow$ Any honest R' mega-sends $(\texttt{READY}, m)$

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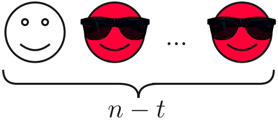

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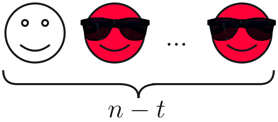

$\Longrightarrow$ **Levels of confidence**

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...

- R_{b-1} $(\mathbf{b-1})$**-receives** m:
  R_{b-1} receives m from S through **all** the b-cast channels **shared with** $\mathbf{b-2}$ **other recipients** $R_1, \ldots, R_{b-2}$.
  $$(R_1, R_2, R_3, R_4, ..., R_{b-2}, R_{b-1})$$

Messages Received from S

R_k **k-receives** m: R_k receives m from S through all the available b-cast channels shared with $k-1$ other recipients $R_1, R_2, \ldots, R_{k-1}$.

$$(R_1, R_2, ..., R_{k-1}, R_k, \star, \star, ..., \star)$$

$\implies$ Any recipient R $(k+1)$-receives m.

$$(R_1, R_2, ..., R_{k-1}, R_k, R, \star, ..., \star)$$

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$$(R_1, R_2, ..., R_{k-1}, R_k, \star, \star, ..., \star)$$

$\implies$ It is possible that $R \in \{R_1, ..., R_{k-1}\}$ $(k-1)$-receives m.

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Levels of Confidence

For a message m, we build the following levels:

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- **Level k**: recipients that k-receive m and *believe* that someone on level $k-1$ is honest and terminated with output m.

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- **Level b**: recipients that do not receive m, but *believe* that someone on level $b-1$ is honest and terminated with output m.

Level 1

When a recipient 1-receives m, it places itself on level 1 and sends notifications to the other recipients.

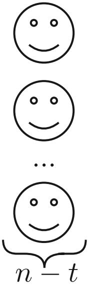
Level 1

  Level 1

Level 1

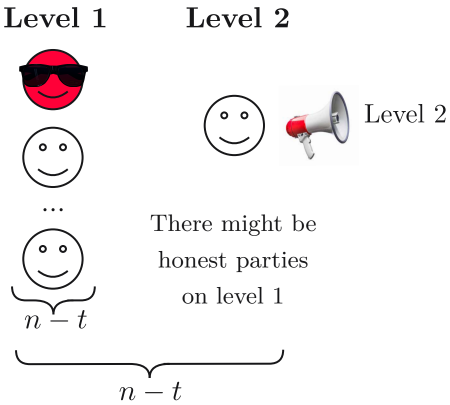
The recipients on level 1 output m if there are $n - t$ recipients that sent notifications for level 1.

Level 1



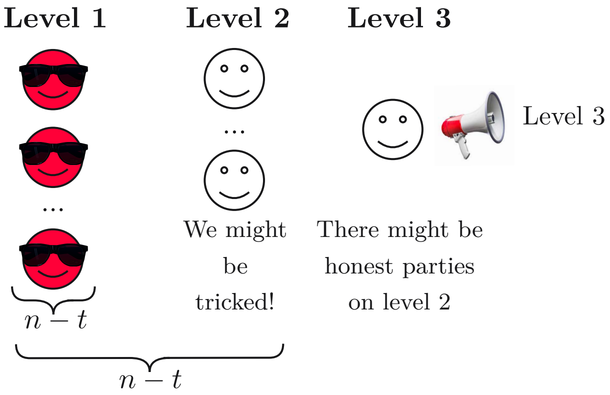
Levels 1 and 2

If a recipient 2-receives m and receives notifications for level 1 from $n-t$ recipients, it sends notifications for level 2 and outputs m.



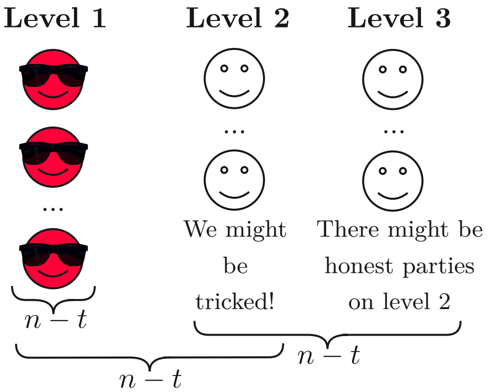
Levels 2 and 3

If a recipient 3-receives m and receives $n - t$ notifications for level 1 and at least one for 2, it places itself on level 3 and sends notifications.

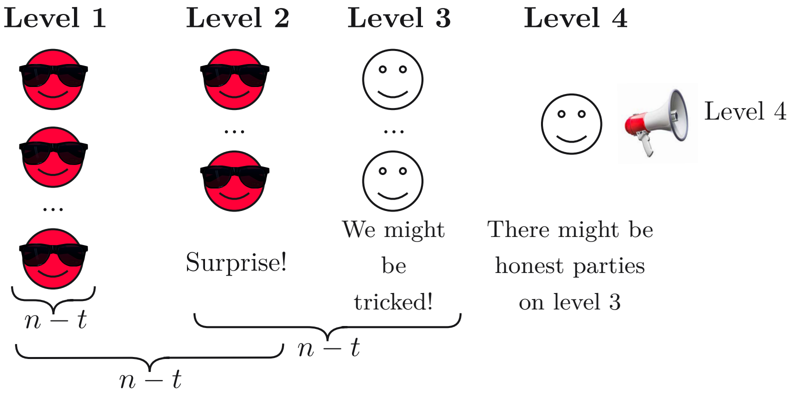


Levels 2 and 3

When there are $n - t$ recipients that sent notifications for levels 2 and 3, the recipients on level 3 output m.



Levels 3 and 4



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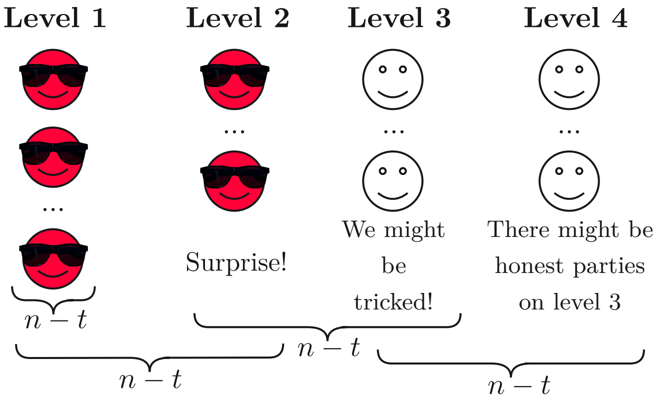
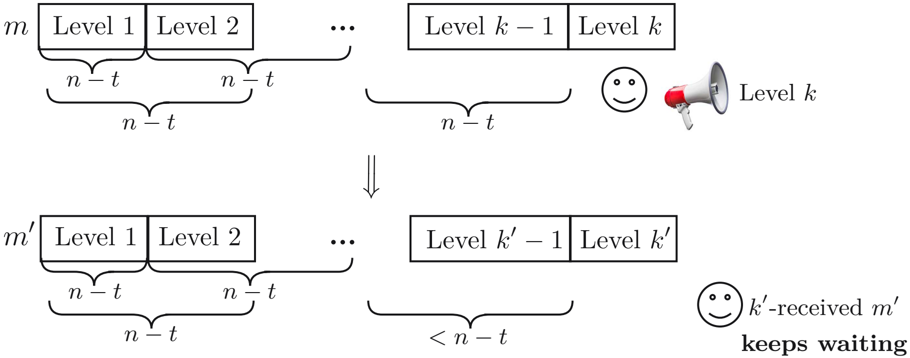


Different Outputs?

t must be small enough such that the honest recipients cannot place themselves on levels for different messages.



Summary

Can we achieve asynchronous reliable broadcast secure against more than $t < n/3$ corruptions by assuming b-cast channels? **Yes!**

What is the trade-off between the strength of the communication network and the corruptive power of the adversary?

- There is no protocol achieving (*nonstop*) reliable broadcast secure against $t \geq \frac{b-1}{b+1}n$ corruptions in the asynchronous setting.
- An **optimal** reliable broadcast protocol for $b = 3$.
- An **almost optimal** reliable broadcast protocol.
- An **optimal** *nonstop* reliable broadcast protocol.