Dual Busy Tone Multiple Access (DBTMA) : A Multiple Access Control Scheme for Ad Hoc Networks

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This paper completely solves hidden and exposed terminal problems

Key Idea & Goals & Main Results

- Key idea:
  - Continuously protect data packet transmission *
  - Use out-band channels to distribute information
- Goals
  - Solve hidden & exposed terminal problems
- Main Results
  - DBTMA: two out-of-band busy tones & RTS
  - Completely solve hidden & exposed terminal problems

Related Works

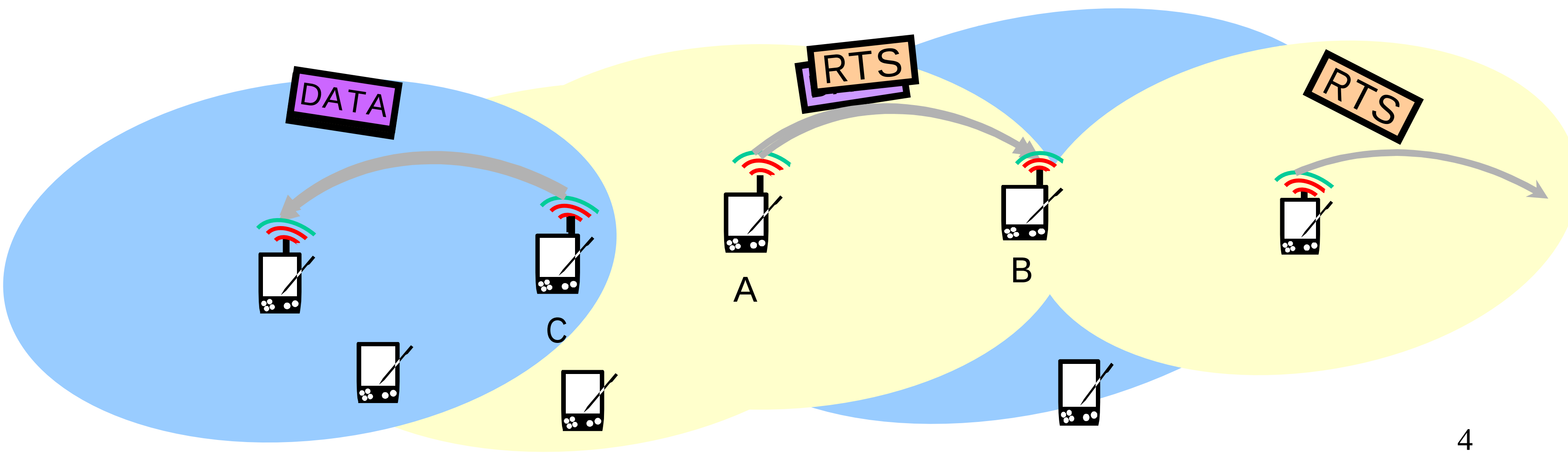
- BTMA (Busy Tone Multiple Access, F. A. Tobagi & L. Kleinrock 1975):
  - Using two channels: data channel & control channel
  - A control center - basestation
  - When base station senses the transmission of a terminal, it broadcasts a busy tone signal to all terminals, keeping them (except the current transmitter) from accessing the channel

- RI-BTMA (Receiver-Initiated Busy Tone Multiple Access, C. Wu & V. O. K. Li 1987)
  - Time is slotted (similar to slotted ALOHA & need time clock synchronization)
  - A packet preamble is sent to intended receiver by the transmitter
  - Receiver sets up an out-of-band busy tone and waits for the data
  - When sensing busy tone, transmitter sends the data packet

- FAMA (Floor Acquisition Multiple Access, C. L. Fuller & J.J Garecia-Luna-Aceves 1995)
  - FAMA-NPC (NPC = on-persistent packet sensing)
    - MACA
  - FAMA-NCS (NCS non-persistent carrier sensing)
    - Sensing carrier before sending RTS
      - If clear, sends RTS
      - Otherwise, waiting a random time, sensing carrier again
    - CTS is more larger than RTS

DBTMA

- Two narrow-bandwidth tones
  - BTt (Transmitter Busy Tone)
    - Set up by the node which has data to send
    - Stop when completing transmitting RTS
  - BTr (Receiver Busy Tone)
    - Set up by the node which receives RTS
    - Stop when completely receives the data packet
- All nodes sensing any busy tone are not allowed to send RTS
- Any node sensing no busy tone is allowed to transmit



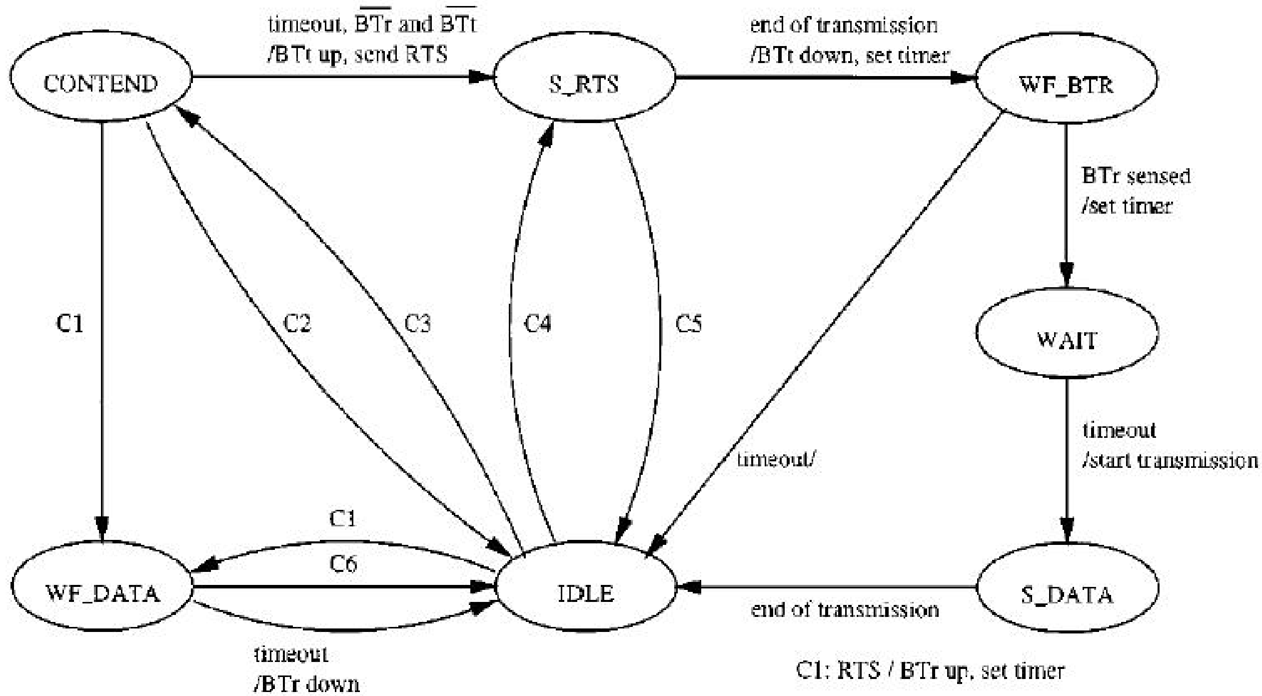
Functionalities of Busy Tones

- BTr (set up by receiver)
  - Notifying the RTS sender that RTS has been received and channel has been acquired
  - Announcing to its neighbor nodes that it is receiving data packet and they should refrain from accessing the channel
- BTt (set up by sender)
  - Providing protection for the RTS packet

Seven DBTMA Operation States

- IDLE
  - Node with on packets to send stays in IDLE state
- CONTEND
  - Node has data to send but it is not allowed to send RTS, it stays in CONTEND state
- S_RTS
  - Node sending RTS is in S_RTS state
- S_DATA
  - Node sending data is in S_DATA state
- WF_BTR
  - RTS packet sender waiting for the ACK from its intended receiver is in WF_BTR state
- WF_DATA
  - Receiver waiting for DATA is in WF_DATA state
- WAIT
  - Node send out RTS and senses BTr and waits a mandatory time, it is WAIT state

Finite State Machine of DBTMA



The statement before "/" is the condition of the transition

The statement after "/" is the action of the transition

C1: RTS / BTr up, set timer

C2: timeout, BTr or BTt/

C3: ready, BTr or BTt / set timer

C4: ready, $\overline{BTr}$ and $\overline{BTt}$ / BTt up, send RTS

C5: sense BTr / BTt down, abort transmission

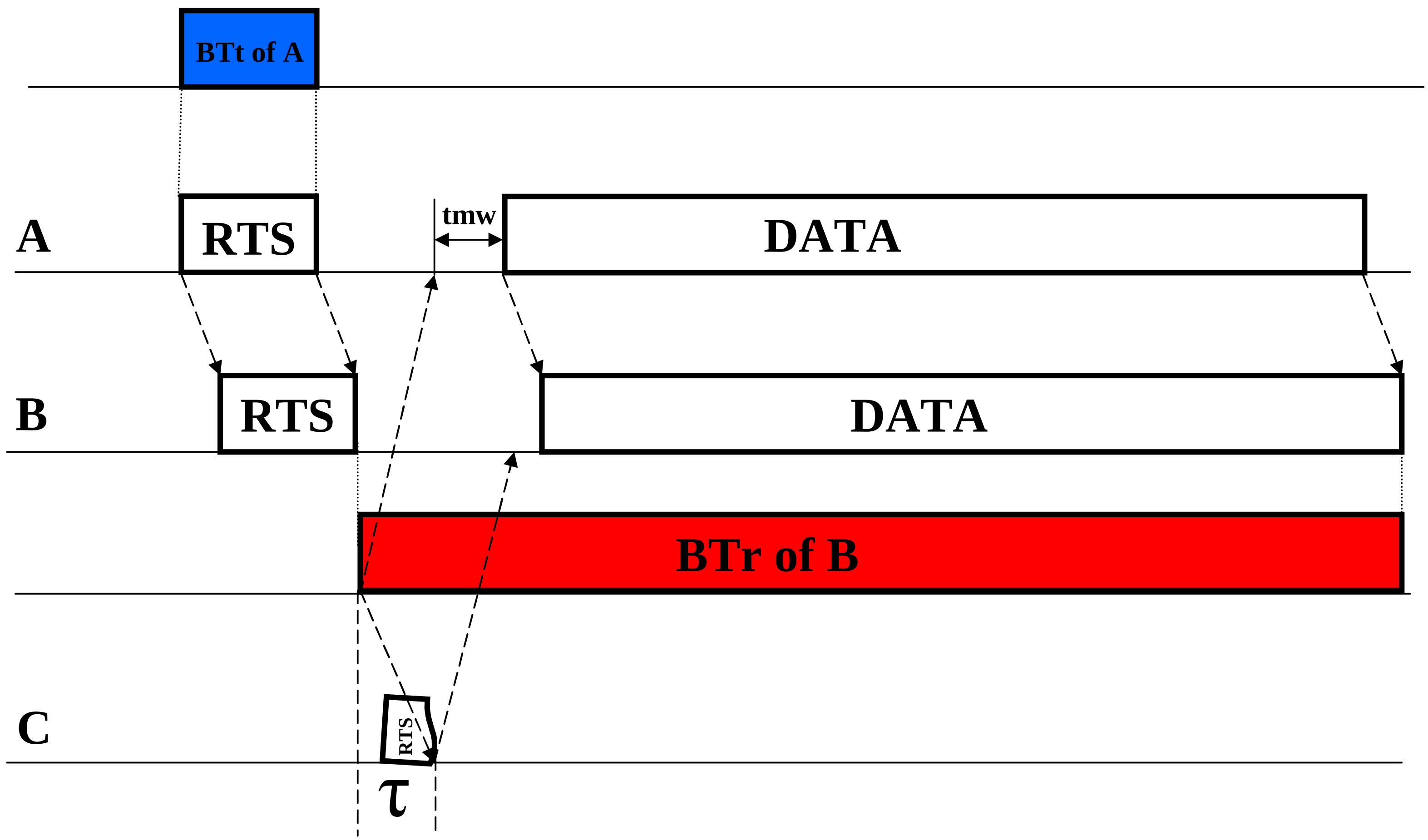
C6: data received / BTr down

More Details for DBTMA

- When A has data to send
  - Senses BTt and BTr
    - If both are clear
      - Turns on BTt
      - Sends out RTS and enters **S_RTS** state
      - Turns off BTt at the end of RTS transmission and gets out **S_RTS** state
      - Sets a timer for expected BTr and enters **WF_BTR** state
        - If BTr is sensed, enters **WAIT** state and waits for tmw, then enters **S_DATA** state and sends data packet
        - Otherwise, timer goes to zero, A goes to **IDLE** state
      - Enters **IDLE** state
    - Otherwise
      - Sets a random timer and goes to **CONTENT** state
        - If BTt or BTr is still sensed when timer goes to zero, A goes to **IDLE** state
        - Otherwise, A turns on BTt and enters **S_RTS** state and sends out RTS if no any busy tone signal is sensed

- When B receives RTS, B turns on BTr and sets a timer for expected data packet and enters **WF_DATA** state
  - If B has not received data packet before timer goes to zero
    - è B turns off BTr and goes to **IDLE** state
  - Otherwise, B receives data packet and turns off its BTr when completely getting the data packet
- When BTr sensed by any Other Node which is in **S_RTS** state, the node aborts it RTS and goes to **IDLE** state

Time Diagram of DBTMA



t_{mw} = Mandatory waiting time

= 2 maximum propagation delay between the transmitter and receiver

$= 2t$

Performance Analysis
(single broadcast domain case)

- Assumptions:
  - A lot of nodes and all nodes are in the same broadcast domain
  - No channel fading, capture effect
  - Packet collisions are the only reason for packet errors
  - Data processing time and transmit/receive turn around time are negligible
  - Bandwidth consumption of busy tones is negligible compared with data channel

DATA Packet Transmission time $= d$

RTS transmission time $= g$

Maximum one way propagation delay $= \tau$

Busy tone detection delay $= \mathrm{t_d}$

Mandatory waiting time $= \mathrm{t_{wm}} = 2t$

All nodes collectively generate Poisson traffic with mean rate l

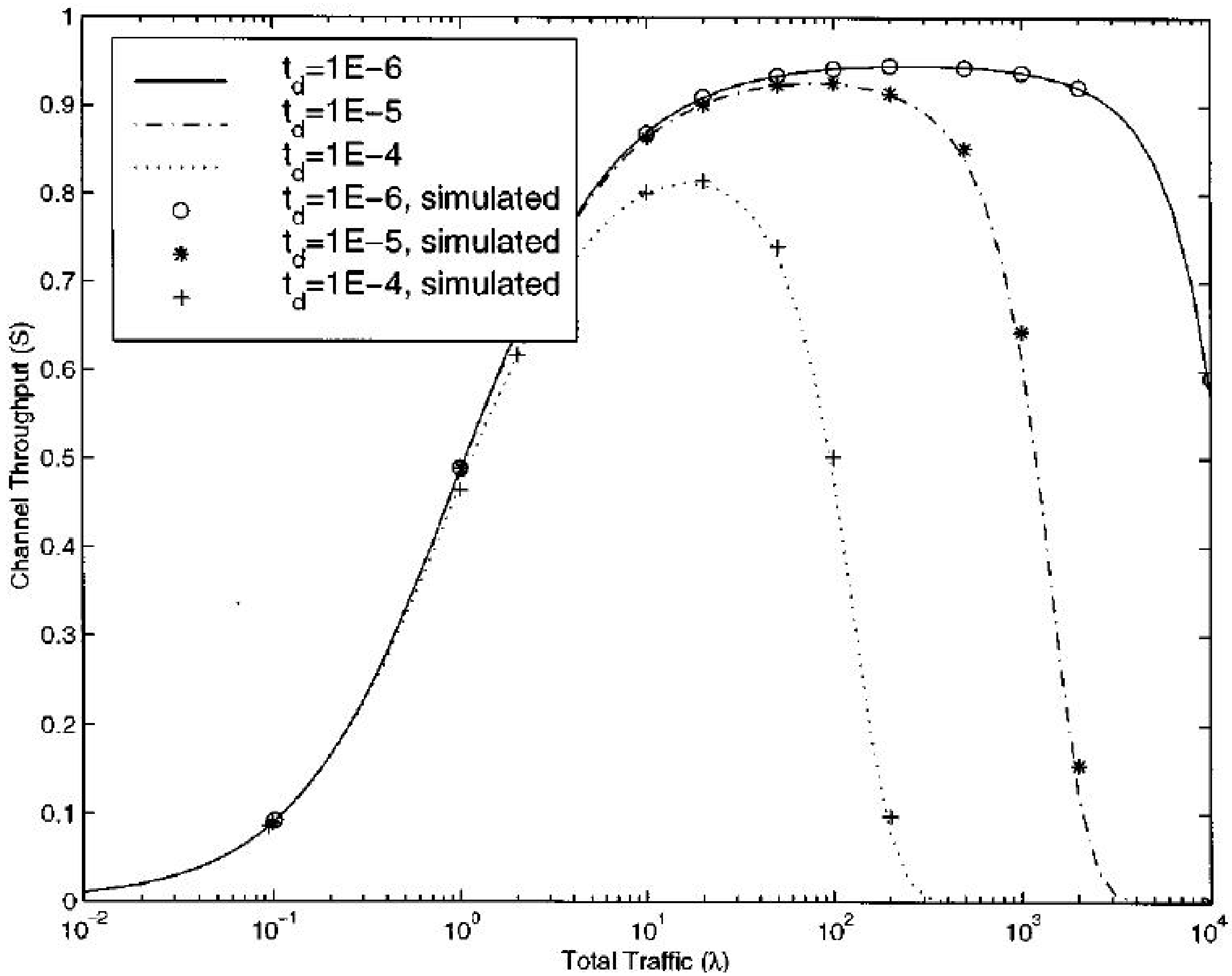
Probability of successful RTS transmission $\mathrm{P_s} = e^{-l(\mathrm{t_d}+t)}$

A successful transmission period $= d + g + \mathrm{t_d} + 6t$

Average failed busy period $\mathrm{T_f} = g + t + 0.5\mathrm{t_d}$

$$\text{Channel throughput} = \frac{\mathrm{P_s} d}{\mathrm{P_s}(d + g + t_d + 6t) + (1 - P_s)T_f + 1/l}$$

Channel Throughputs of DBTMA (Single Broadcast Region)



Capacity = 1 Mbps

Data packet = 4096 b

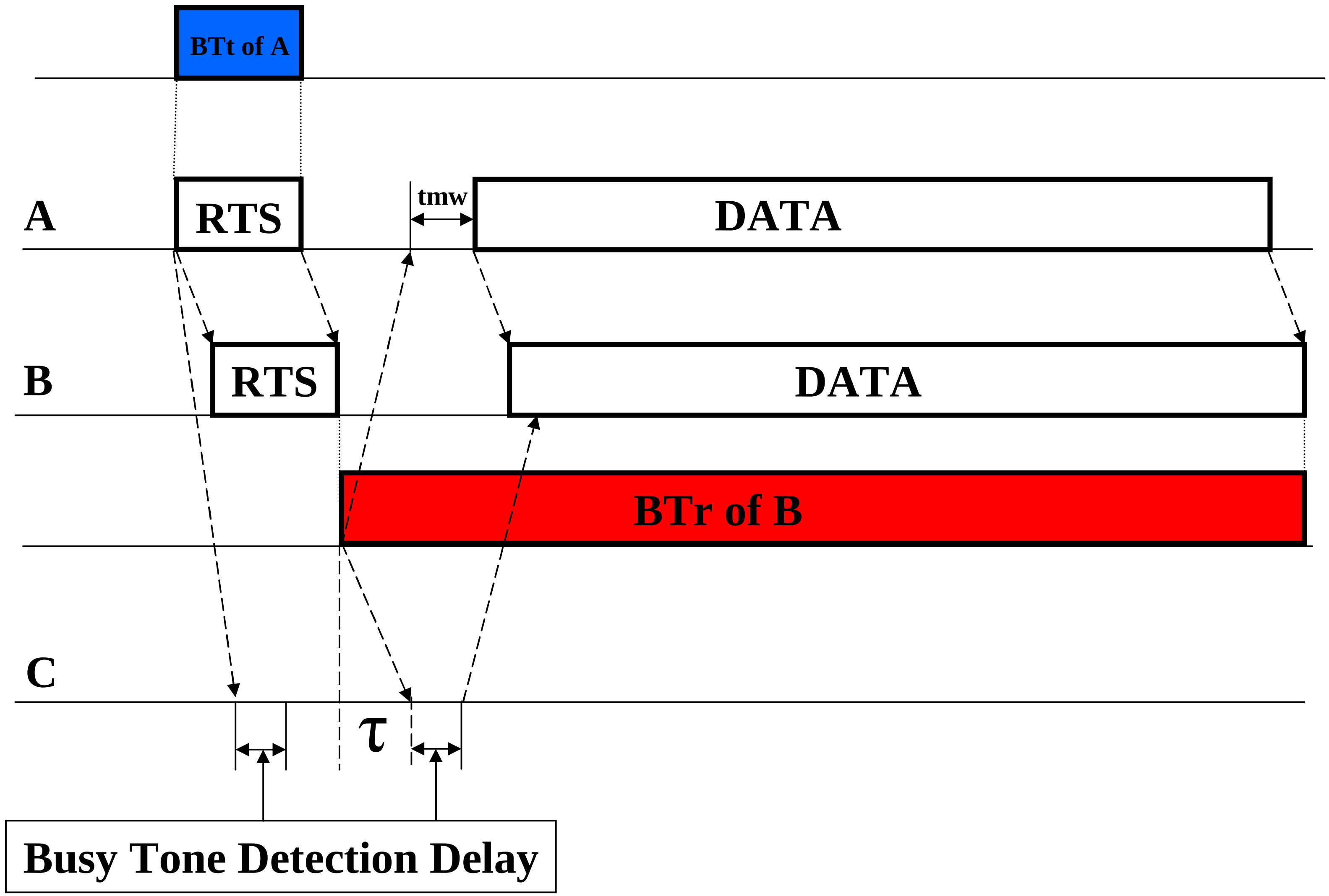
RTS = 200 b

20 nodes in 50 by 50 m^2

Radio transmission range = 35m

Maximum propagation delay = 0.12 μs

Impact of Busy Tone Detection Delay



Channel Throughput (ad-hoc network)

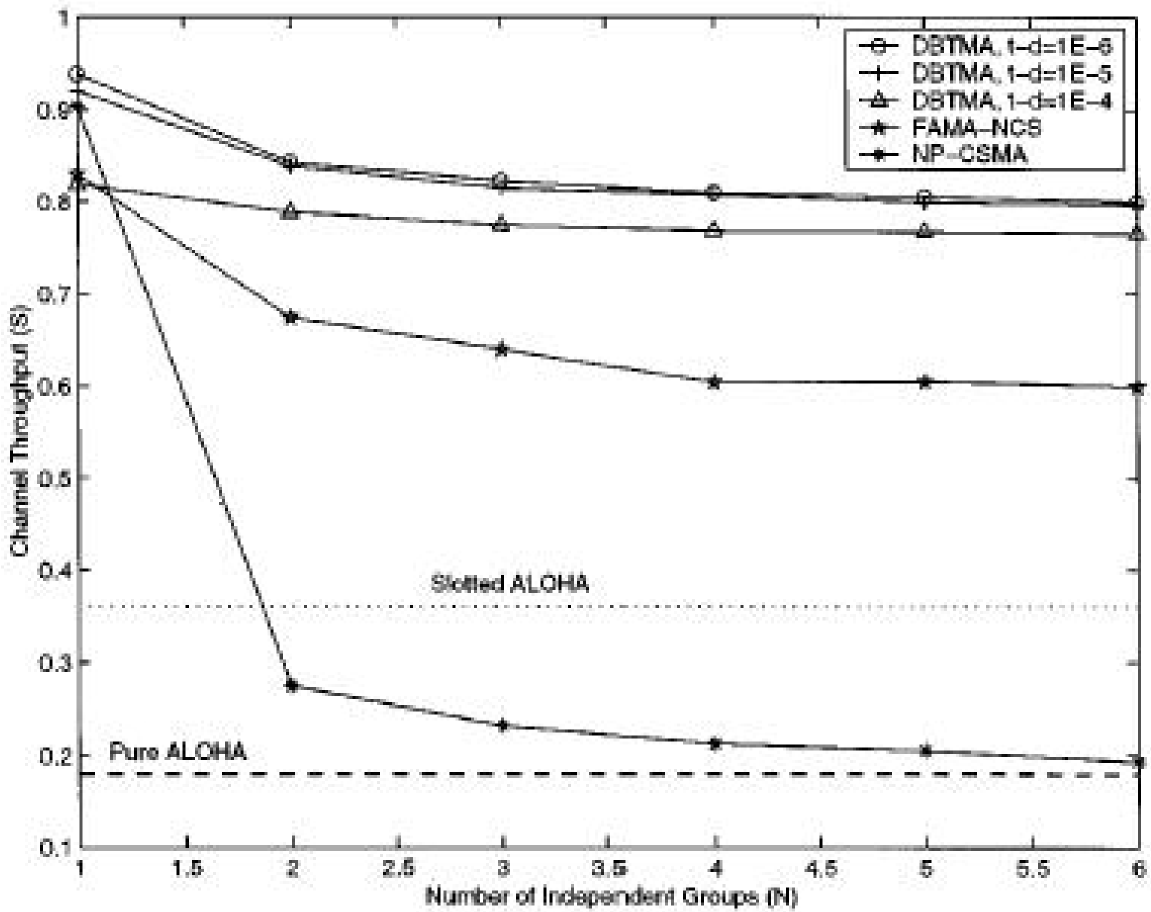
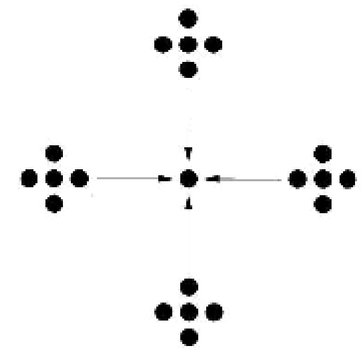


Fig. 7. Channel throughput of DBTMA with different N.



Capacity = 1 Mbps

Data packet = 4096 b

RTS = 200 b

Radio transmission range = 2 km

Propagation delay = 6.7 μs

Comparisons of Channel Throughput

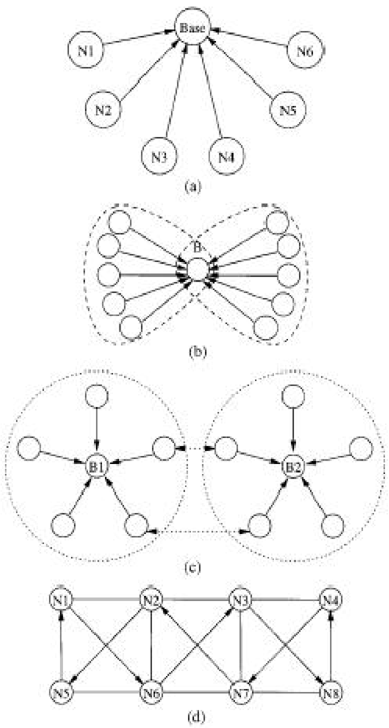


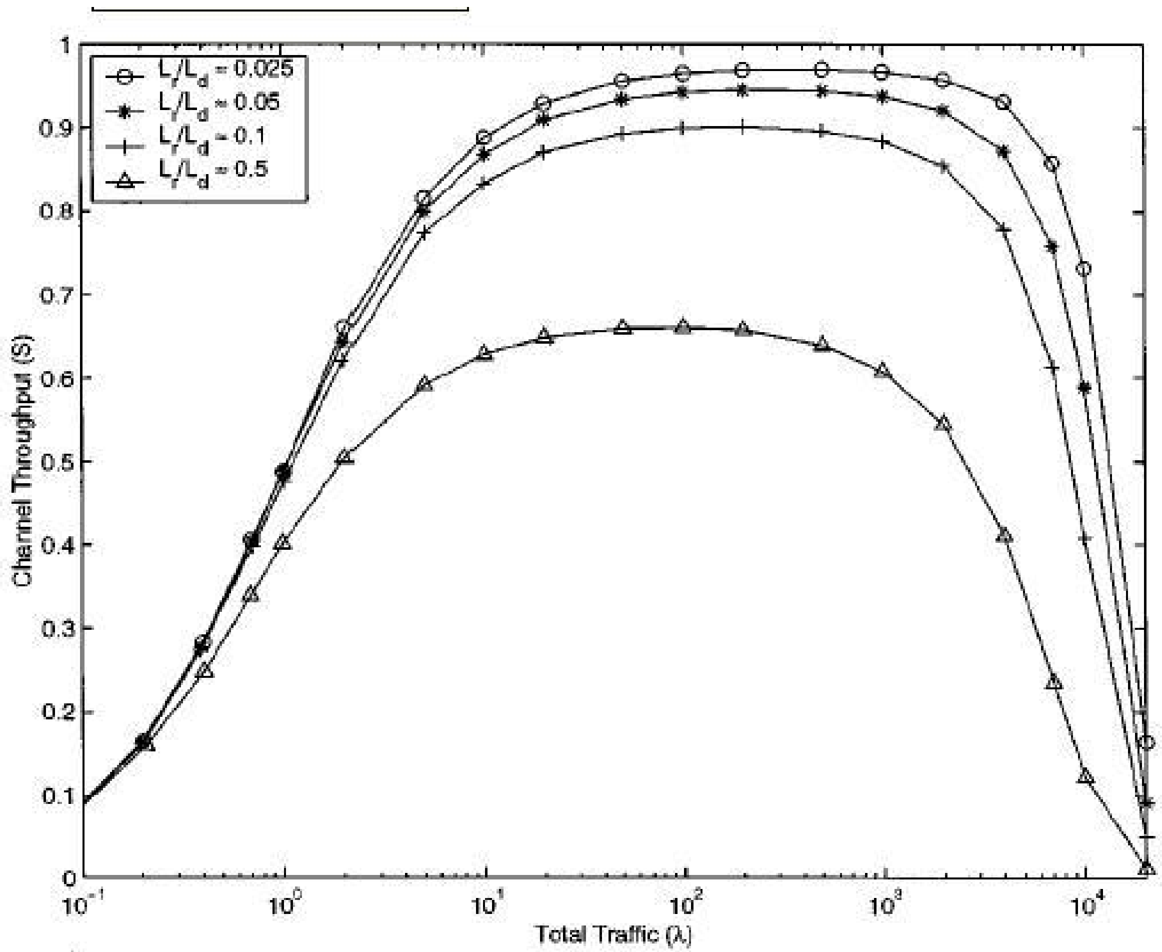
Fig. 8 Simulated topologies.

Configuration	DBTMA	FAMA-NCS	MACAW
(a)	.94	.78	.63
(b)	.84	.59	.49
(c) B1	.94	.75	.45
(c) B2	.94	.75	.39
(d) average	.69	.49	.06
(d) N1, 4, 5, 8	.90	.57	.07
(d) N2, 3, 6, 7	.48	.42	.05

Fig. 9. Channel throughput comparisons.

Capacity = 256 kbps Data packet = 4096 b RTS = 200 b
Each node are 6 km from each other Propagation delay = 20 μs

Comparison of Different Length of Control Packet



Full connected network

Every node randomly choose its destination for each generated data packet

Capacity = 1 Mbps

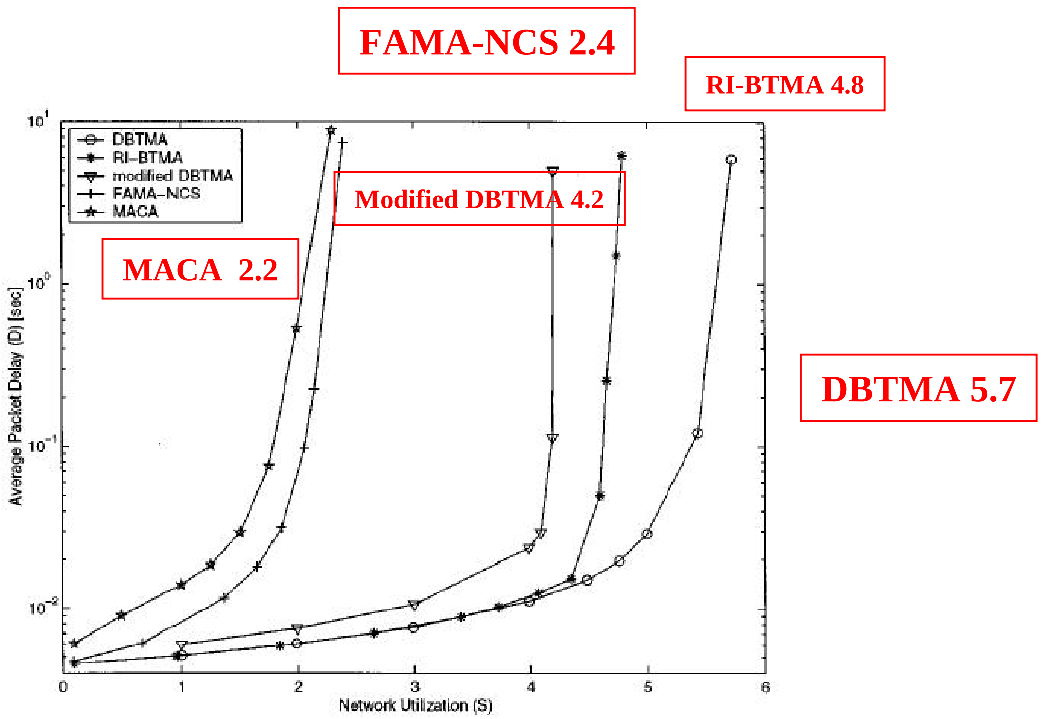
Data packet size =4096 b

20 nodes in 50 by 50 m^2

Radio transmission range = 35 m

Propagation delay = 0.12 μs

Network Utilization of DBTMA in Multi-Hop Networks



50 nodes in 400 by 400 m^2

Radio transmission range = 100 m

RTS size = 200 b

Packet size = 4096 b

Capacity = 1 Mbps

Propagation delay = 0.33 μs

Packet arrival at each node is Poisson distributed

Each node randomly selects a neighbor as the destination of each packet

Summary

- DBTMA does solve hidden & exposed terminal problems
- DBTMA is based on the idea presented in RI-BTMA
- Some idea
  - Using some kind of out-of-band control channel to propagate some info to achieve some performance targets