IEEE802ワイアレス技術フォーラム

メッシュ・ルーティング
最新動向解説

２００７年7月１８日　（当日資料の抜粋）

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MANET

(Mobile Ad-hoc Networks)

http://www.ietf.org/html.charters/manet-charter.html

目的

The purpose of the MANET working group is to standardize IP routing protocol functionality suitable for wireless routing application

MANETにおけるプロトコル標準化の現状

- 2007年6月末現在の状況 http://www.ietf.org/html.charters/manet-charter.html
  - **Internet-Drafts:**
    - Dynamic MANET On-demand (**DYMO**) Routing
    - Simplified Multicast Forwarding for MANET
    - The Optimized Link State Routing Protocol version 2（**OLSRv2**）
    - Generalized MANET Packet/Message Format
    - MANET Neighborhood Discovery Protocol (NHDP)
    - Internet Assigned Numbers Authority (IANA) Allocations for the Mobile Ad hoc Networks (MANET) Working Group
    - Jitter considerations in MANETs
    - Representing multi-value time in MANETs
  - **Request For Comments:**
    - Mobile Ad hoc Networking (MANET): Routing Protocol Performance Issues and Evaluation Considerations (RFC 2501)
    - Ad Hoc On Demand Distance Vector (**AODV**) Routing (RFC 3561)
    - Optimized Link State Routing Protocol (RFC 3626) （**OLSR**）
    - Topology Dissemination Based on Reverse-Path Forwarding (TBRPF) (RFC 3684)
    - The Dynamic Source Routing Protocol (DSR) for Mobile Ad Hoc Networks for IPv4 (RFC 4728)

Dynamic MANET On-demand Routing ： DYMO

- オンデマンド型　ルーティング・プロトコル
  - AODVを拡張する過程で名前をDYMOと変えた
  - 提唱者はAODVと同じ “Dr. C. Perkins”
- 最新のInternet-draft (draft-ietf-manet-dymo-10.txt)より以下抜粋

The Dynamic MANET On-demand (DYMO) routing protocol enables reactive, multihop unicast routing between participating DYMO routers. The basic operations of the DYMO protocol are route discovery and route management. During route discovery, the originator's DYMO router initiates dissemination of a **Route Request (RREQ)** throughout the network to find a route to the target's DYMO router. During this hop-by-hop dissemination process, each intermediate DYMO router records a route to the originator. When the target's DYMO router receives the RREQ, it responds with a **Route Reply (RREP)** sent hop-by- hop toward the originator. Each intermediate DYMO router that receives the RREP records a route to the target, and then the RREP is unicast hop-by-hop toward the originator. When the originator's DYMO router receives the RREP, routes have then been established between the originating DYMO router and the target DYMO router in both directions

DYMO uses sequence numbers to ensure loop freedom [Perkins99]. **Sequence numbers** enable DYMO routers to determine the order of DYMO route discovery messages, thereby avoiding use of stale routing information.

Ad Hoc On-Demand Distance Vector Routing (AODV)

[Perkins99Wmcsa]

- オンデマンド型　ルーティング・プロトコル
  - オンデマンド型のDSR（Dynamic Source Routing)との比較
    - DSRはpacket headersにsource routes情報を保有することでLoopを回避。
    - 欠点はスケーラブルではなく、動的リカバリが困難である点
  - AODVは
    - Source Routing方式ではなく各ノードで経路テーブルを参照してNext Hopを決定することでDSRの課題を解決
    - 必要な経路情報のみを管理している点ではDSRと同じくオンデマンド型の特長を持つ

Link State Routing [Huitema95]

- 各ノードは定期的にリンク情報を隣接ノードに通知
- ステータスが変化したリンク情報も通知
- 隣接ノードから受信したリンク情報はRe-broadcast → リンク・ステータスが変化しつづけるネットワークでは常にflooding発生（無線メッシュ環境における課題）
- 各ノードは上記手順で得られたリンク情報を基に宛先ノードへの最適経路を算出
  - Dijkstra アルゴリズム
  - QoS Routingなどには適している

OLSR：Optimized Link State Routing

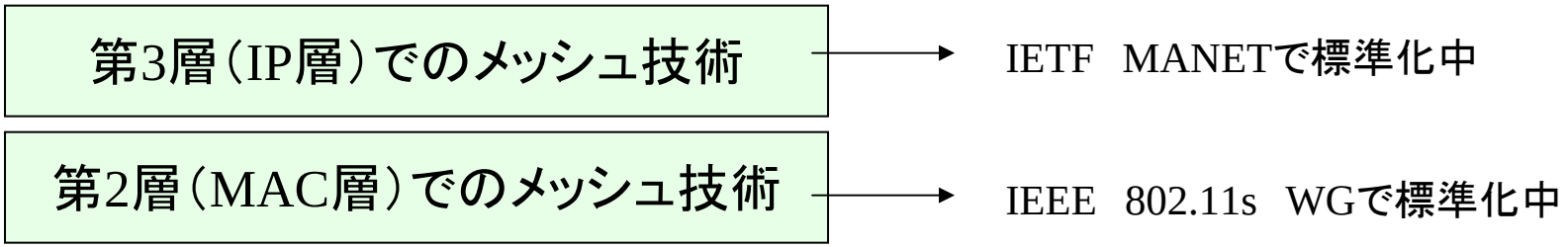
[Jacquet00ietf,Jacquet99Inria]

- リンク情報伝送における“flooding”問題を軽減することでLink State Routingをアドホック・ネットワークで利用可能とするアプローチ
- 受信したリンク情報を転送するノードを“Multipoint Relays ”ノードに限定し、全ての隣接ノードに伝えることをしない
- ノードXにとっての“Multipoint Relays ”の定義
  - ノートXの全ての“two-hop neighbor” はノードXの“Multipoint Relays” の少なくとも一つの“one-hop neighbor”とならねばならない
  - 各ノードが送信するbeacon情報に隣接ノード・リスト情報を含むことで“Multipoint Relays” は算出可能

IEEE802.11s　Mesh

IEEE802.11s

- 目的
  - The 802.11s standard aims to define a MAC and PHY for networks that support ESS Mesh functionality.
- 位置付け



802.11s WG これまでの経緯

- 2003年にIEEE802.11 study group として検討開始
- 2004年7月にIEEE802.11　Task Groupへ
- 2005年に15提案が提出、検討を経て2つの流れに“SEE-Mesh” and “Wi-Mesh“）に統合
- 2006年1月に 一つのjoint proposalとして提出されこれをもとにドラフト仕様 D0.01を作成。このドラフトは2006年3月にVotingを経て承認された
- D0.0.1を基にさらに改良を加えドラフト仕様 D1.00を作成
- 2006年11月にD1.00に関するVotingを実施するものの75%の合意に達せず保留
- 2007年4月時点でのドラフト仕様はD1.02

提出された 802.11s Proposals

Proposal	#	Contact	Jul-05		Sep-05		Nov-05		Jan-06	
		Short Name	Ratio	Rank	Ratio	Rank	Ratio	Rank	Ratio	Rank
B/G		Joint SEE Mesh Wi-Mesh								
G	7	SEE Mesh	83.58%	1	82.84%	1	77.67%	1	Defer until	
B	31	Wi-Mesh Alliance (WiMA)	77.16%	2	58.93%	2	39.79%	2	March	
H	9	Mesh Networks Alliance (MNA)	60.62%	4	35.54%	3	15.07%	3		
J	35	Proactive Mesh	53.89%	5	28.16%	4	(merged into G:7)			
M	22	Common Control Channel	34.05%	10	15.17%	5				
A	8	Mesh DCF	26.02%	12	11.18%	6				
K	32	Samsung	76.82%	3	(merged into G:7)					
C	6	Cooperative Protocol	52.16%	6	(merged into B:31)					
E	5	Hybrid Mesh Routing	51.03%	7	(merged into B:31)					
L	19	Siemens	50.92%	8	(merged into G:7)					
N	18	SNOW Mesh	48.66%	9	(merged into G:7)					
I	20	Tree Based Routing (TBR)	33.48%	11	(merged into G:7)					
F	3	Dynamic Backbone	18.93%	13						
D	17	Intermittent Periodic Transmit (IPT)	11.98%	14						
O	29	Self Organizing	10.61%	15						

Table from:
"Proposals for TGs", IEEE 802.11-05/0597r20

参照: http://www.csie.nctu.edu.tw/~yctseng/WirelessNet06-02/ieee802-11s-see-2.ppt

当頁内容は以下資料からの引用です
ieee802.org/802_tutorials/nov06/802.11s_Tutorial_r5.pdf (W.Steven Conner, Intel, et al)

802.11s Routing

- HWMP: Default Routing Protocol
- RA-OLSR: Optional Routing Protocol

802.11s プロトコル

- 基本ルーテイングプロトコル（必須）
  - Hybrid Wireless Mesh Protocol（HWMP)
    - AODV (RFC 3561[1]) ならびに
    - ツリー型（Tree-based）・プロトコル

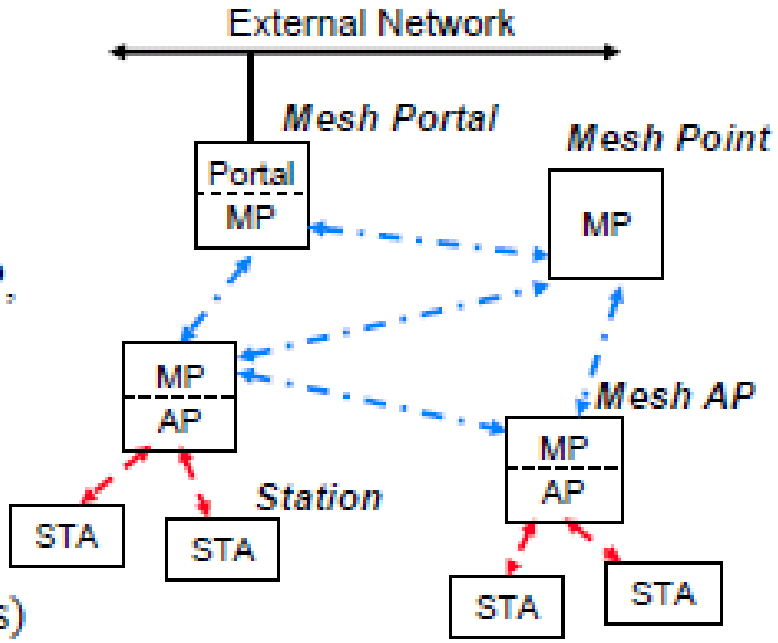
- オプションで追加実装可能なルーテイング・プロトコル
  - Radio Aware Optimized Link State Routing

    これは前述のOLSR (RFC 3626[2])をベースにした拡張プロトコル

当頁内容は以下資料からの引用です
ieee802.org/802_tutorials/nov06/802.11s_Tutorial_r5.pdf (W.Steven Conner, Intel, et al)

Device Classes in a WLAN Mesh Network

- **Mesh Point (MP)**: establishes peer links with MP neighbors, full participant in WLAN Mesh services
  - Light Weight MP participates only in 1-hop communication with immediate neighbors (routing=NULL)
- **Mesh AP (MAP)**: functionality of a MP, collocated with AP which provides BSS services to support communication with STAs
- **Mesh Portal (MPP)**: point at which MSDUs exit and enter a WLAN Mesh (relies on higher layer bridging functions)
- **Station (STA)**: outside of the WLAN Mesh, connected via Mesh AP



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Default Routing protocol for Interoperability

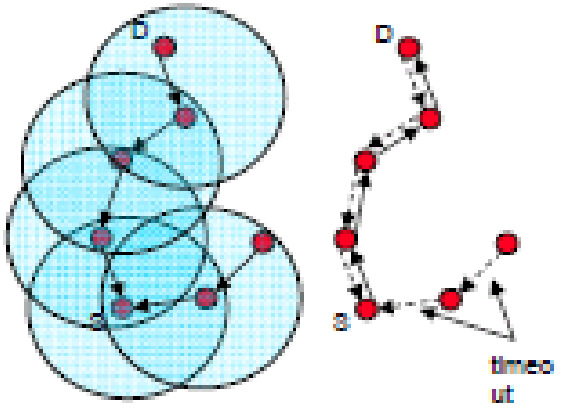
Hybrid Wireless Mesh Protocol (HWMP)

- **Combines the flexibility of on-demand route discovery with efficient proactive routing to a mesh portal**
  - On demand routing offers great flexibility in changing environments
  - Pro-active tree based routing is very efficient in fixed mesh deployments
  - The combination makes it suitable for implementation on a variety of different devices under consideration in TGs usage models
    - from CE devices to APs and servers
- **Simple mandatory metric based on airtime as default, with support for other metrics**
  - Extensibility framework allows any path selection metric (QoS, load balancing, power-aware, etc)

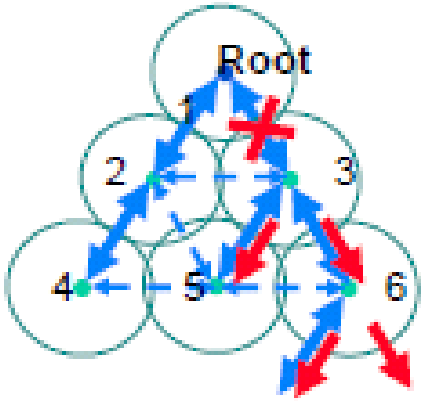
当頁内容は以下資料からの引用です
ieee802.org/802_tutorials/nov06/802.11s_Tutorial_r5.pdf (W.Steven Conner, Intel, et al)

Hybrid Wireless Mesh Protocol (HWMP)

- **On demand routing is based on Radio Metric AODV (RM-AODV)**
  - Based on basic mandatory features of AODV (RFC 3561)
  - Extensions to identify best-metric path with arbitrary path metrics
  - Destinations may be discovered in the mesh on-demand



- **Pro-active routing is based on tree based routing**
  - If a Root portal is present, a distance vector routing tree is built and maintained
  - Tree based routing is efficient for hierarchical networks
  - Tree based routing avoids unnecessary discovery flooding during discovery and recovery



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ieee802.org/802_tutorials/nov06/802.11s_Tutorial_r5.pdf (W.Steven Conner, Intel, et al)

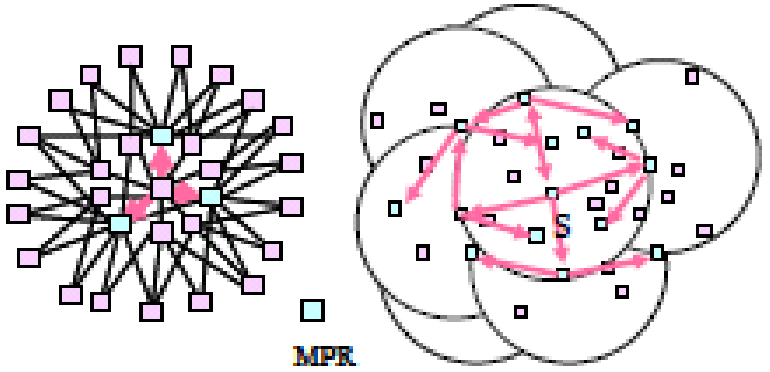
Example Optional Path Selection Protocol
Radio Aware OLSR (RA-OLSR)

- **Proactively maintains link-state for routing**
  - Changes in link state are communicated to "neighborhood" nodes
- **Extensible routing scheme based on the two link-state routing protocols:**
  - OLSR (RFC 3626)
  - (Optional) Fisheye State Routing (FSR)
- **Extended with:**
  - Use of a radio aware metric in MPR selection and routing path selection
  - Efficient association discovery and dissemination protocol to support 802.11 stations

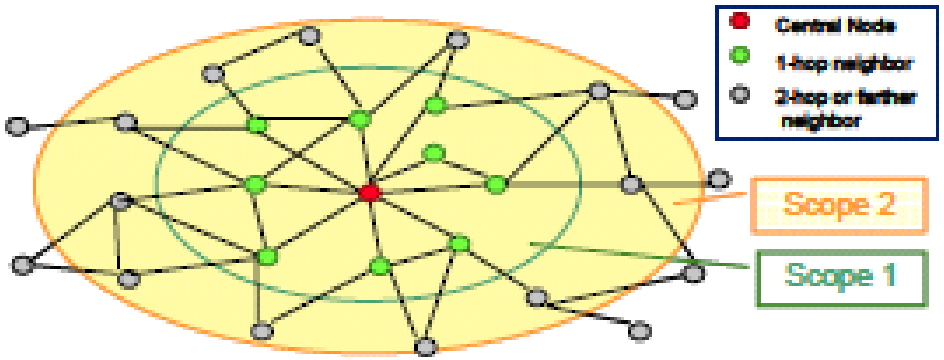
当頁内容は以下資料からの引用です
ieee802.org/802_tutorials/nov06/802.11s_Tutorial_r5.pdf (W.Steven Conner, Intel, et al)

RA-OLSR – Key Features

- **Multi Point Relays (MPRs)**
  - A set of 1-hop neighbor nodes covering 2-hop neighborhood
  - Only MPRs emit topology information and retransmit packets
    - Reduces retransmission overhead in flooding process *in space*.



- **(Optional) message exchange frequency control (fish-eye state routing)**
  - Lower frequency for nodes within larger scope
    - Reduce message exchange overhead *in time*.



802.11s WG 2007年スケジュール
Schedule Projected at Melbourne, Victoria (September) Meeting

当ページの内容は以下引用
IEEE 802.11-06/1753r2
By Donald E. Eastlake（Motorolla)

- January 2007 (London, England)
  - Comment Resolution
- March 2007 (Orlando, Florida)
  - First Letter Ballot Re-circulation authorized
- May 2007 (Montreal, Quebec)
  - Second Letter Ballot Re-circulation
- July 2007 (San Francisco, California)
  - Third Letter Ballot Re-circulation
- September 2007 (Waikoloa, Hawai‘i)
  - Sponsor Ballot Authorization by WG
- November 2007 (Atlanta, Georgia)
  - Sponsor Ballot Comment Resolution