PART I Keynote Speeches

第一部分 特邀报告

THE ACTUALITY AND FORECAST OF IT INFORMATION TECHNOLOGY

ZHAO ZI-SEN

Wuhan Research Institute of Posts and Telecommunications

Hubei Wuhan 430074 China

Abstract：The report begins with fiber communication, wireless communication, Internet and tri-networks integration, relates to communication, broadcast, computer, component and others area. The present and future of IT information technology is introduced to reader. The report content is wide, deep, accademic and interesting, explains profound things in simple ways and coming with pictures and words.
Key words：Communication, Computer, Internet, tri-networks integration

IT 信息技术的现状和展望

赵梓森

武汉邮电科学研究院，湖北 武汉 中国 430074

摘要：报告从光纤通信，无线通信，因特网到三网融合出发。涉及了通信加广播，计算机加消费品元器件及其他等诸多领域。介绍了 IT 信息技术现在与未来，内容既广泛又深入，既具有科学性又具有趣味性，图文并茂，动画结合，可谓深入浅出。

关键词：通信；计算机；因特网；三网融合

1. 概述

IT 信息技术的产业，有称为 5C，即：通信、计算机、消费品、元件和内容。

讨论重点在通信：

光纤通信与其他通信手段的比较：

传输技术	容 量	相当电话数	放大站距
电缆	6MHz(模拟)	1800 路	6 公里
微波通信	140Mb/s	1920 路	50 公里
电缆电视	500~1000MHz	100 路电视	50~100 米
光纤通信	2.5~3000Gb/s 3~	3600 万路	100 公里

可以毫不夸张地说：光纤通信引起通信技术一场革命。光纤之父英籍华人高锟在 2009 年获得 Nobel 奖金。2010 年 NTT 在 OFC 国际光纤通信大会中报道了速率为 69.1Tbps 传输 240km 的实验系统，系统采用了 DPSK，QAM ，PM 和相干接收等新技术。中国武汉邮电科学研究院在 2005 年采用国产设备在上

海到杭州开通了速率为 3.2Tbps 的通信线路，它是至今世界速率最大的实用线路。

当今，发达国家正在发展 100Gbps 单信道高速系统。如：Nortel，Verizon 等公司，在 Marshall-Longview 间已建有试验线路。光纤到户 FTTH 是用户的理想。日本已有 50%以上采用 FTTH。中国采用光纤到大楼（门栋）较多。近来兴建高楼较多，有光纤到楼层 FTTF。光纤的接入网采无源光网 PON 比较经济。目前，无线通信可以采用移动电话和无线接入网予以实现。中国第三代移动电话在 2009 年 5 月 13 日正式启动。2G-GSM 850/900 可承受 250km/hr，GSM1800 可承受 130km/hr，但它在我国近来新建的 370km/hr 高速列车通话困难。而 3G 则可在高速列车使用。无线接入网包括：

技 术	带 宽	覆盖范围	用 途
WLAN	100Mbps	x km	专用网
WiFi	54Mbps	100km	家庭
WiMAX	70Mbps	7 km	专用网

中国大陆官方没有给 WiMAX 提供频谱。温家宝总理在国务院务会议中决定：加快推进电信网、广播电视网和互联网的三网融合。市民通过一张网，可打电话、看电视、上网。符合条件的广播电视企业：可经营增值电信业务和部分基础电信业务、互联网业务；符合条件的电信企业：可从事部分广播电视节目生产制作和传输。并规定了阶段性目标：

2010 年至 2012 年：重点开展广电和电信业务双向进入试点

2013 年至 2015 年：全面实现三网融合。

2010 年 6 月 30 日 国务院公布三网融合第一批试点市区，包括：北京、上海、大连、哈尔滨、南京、杭州、厦门、青岛、武汉、长株潭地区、深圳、绵阳。中国国情：由于在经济不发达地区的需要，必须要有广播电视（不一定有通信网）。在这些地区，可利用广电网发展通信业务，如湖北的鄂州。

2. 目前中国电视网有下列任务：

1）有线电视数字化高清化

2）发展 CMMB 移动电视

3）广电总局规定 “一省一网”， 建立省统一运营网络公司

4）三网融合网络需要的双向改造

此外，还在考虑下一代广电网 NGB ：核心网带宽 Tbps，保证用户带宽 60Mbps。三网融合开发了互联网电视机，即有互联网功能的电视机。用户将电视机连接网线，即可进入“内容平台”，可方便地用遥控器选择所需要的视频节目。广泛受到老百姓的欢迎。这样使电视机制造业产生了巨大商机。

世界正发展“云计算”。发展“云”的公司包括：微软、鸦虎、苹果、Google、亚马逊 ---等。“云”特点包括：提供资料，提供软件，提供存储容量，存文件（E-mail 等），提供计算能力，不收费（运行靠广告费维持）。云计算机最好的解释：“网络就是计算机”。广东东莞筹建成国内首个自主产权的云计算平台。由于高清晰度视频内容数据量太大，输入计算机耗时太长。国际上提出：USB4.0 是采用光纤传输的接口。支持者包括：Intel，Corning，富士康，Sony，TDK 等。元器件是设备制造的基础。通信需要有光电子器件，特别是提高通信速度和容量，就需要新的光电器件，如：MQW (Multi-Qutum Well)多量子阱激光器，

掺铒光纤放大器，RAMAN 光放大器，**AWG** 光栅阵列波导光滤波器，偏振复用器，光开关等。如同微电子器件、光器件也需要集成化，采用 PLC 平面光线路技术使光器件集成化。信息的内容在电子化数字化的作用下，有巨大的变迁。数字化带来的影响，如：数字音响，数字影视，数字相机，数字图书，电子图书等。计算机对创作带来的影响，如：MIDI 合成音乐，3D 动画等。

新兴的内容产业“文化创意产业”，创意经济范畴包括 13 个行业，即：广告，建筑，艺术和文物交易，工艺品，设计，时装设计，电影，互动休闲软件， 音乐，表演艺术，出版，软件，电视广播等。（英国政府的意见）。文化创意产业的经济效益巨大，单动画片全球市场规模：750 亿美元。

注：在教育部中南地区高等学校电子电气基础课教学研究会 / 第二十届学术年会上报告，但由于是动画媒体形式，只好节录，略写如下文本，谨供参考

作者简介

赵梓森 男，中国工程院院士，1953 年毕业于上海交通大学电信系。历任武汉邮电学院讲师，邮电部激光通信研究所所长、总工程师，武汉邮电科学研究院副院长、总工程师、高级工程师。国际电气电子工程师协会高级会员。1958 年获全国五一劳动奖章。是第六届全国人大代表。中国最早提出发展光纤通信者之一，并进行了中国第一次光纤通信的试验，为开创中国的光纤通信事业作出贡献。撰有《用 O－－∞法解网络》等论文，著有《数学光纤通信系统原理》等

BASIC REQUIREMENTS OF ELECTRIC AND ELECTRONIC FUNDAMENTAL COURSES AND PROFESSIONAL ACCREDITATION OF ENGINEERING EDUCATION

WANG ZHI-GONG

Southeast University, Nanjing, 210096 China

zgwang@seu.edu.cn

Abstract：This paper introduces the background of the preparation of the basic requirements of electric and electronic fundamental courses. The prophase works are briefly reviewed and the works in 2010 are put forward. Then, the necessity and the standards of the professional accreditation of engineering education and its relationship with the reform of the engineer system are given. At last, some respects of the professional accreditation of engineering education are discussed.

Keywords：Basic requirements of electric and electronic fundamental courses, professional accreditation of engineering education；engineer system

电子电气基础课程教学基本要求与工程教育专业认证

王志功

东南大学 射频与光电集成电路研究所，江苏 南京 中国 210096

摘要：本文主要介绍“教学基本要求”的制订背景。首先对前期工作加以简要回顾，在此基础上对 2010 年工作的进展提出了一些想法。接下去论述了工程教育专业认证的必要性，介绍工程教育专业认证标准和工程教育专业认证与工程师制度改革的关系。最后，介绍“电气信息类专业”工程教育专业认证有关问题

关键词：教学基本要求；工程教育专业认证；工程师制度改革

1．基础课程教学基本要求制定的背景

1998 年是中国现代教育史上一个值得纪念的一年。这一年我国实施科教兴国战略，高等教育开始实现历史跨越。其中，有两件标志性的大事：一是启动了 985 工程，全国重点建设 30 多所大学，向世界一流大学迈进；二是高校大规模扩大招生，1999 年到 2001 年，3 年时间年招生人数翻了一番，2001 年全国各类高等院校招收人数达到 500 万人。2002 年招 643 万，入学率 13.2%。由此，我国大学从“精英教育”转变到了“大众教育”。

由于这种转变，大学入校学生的知识水平、智力水平和学习能力相对降低；为了应对扩招学生的教学，一批大专升级成大学，一批民办大学建立。在这些学校内，教师的知识水平和教学能力自然难与原有大学教师相比。另外，不同类型学校的不同水平的教师编写一大批不同水平的教材。这样，教学质量的问题不可避免地暴露出来。

针对教学质量存在上述问题，教育部教高司 2003 年 8 月 28 日发出[2003]141 号文件，为加强理工科

各教学指导委员会的工作，更好地发挥理工科各教学指导委员会的作用，决定依托教学指导委员会开展高等学校科学教育的战略和对策研究工作。对各教学指导委员会开展的各学科专业发展战略研究和制定学科专业教学规范两项工作，基础课程教指委则负责制订相关课程的教学基本要求。制订专业规范和基础课程教学基本要求的原因在于：大众化的高等教育也要有最低质量标准，我国高等教育还处于专业教育阶段，而非通才教育；一般院校迫切需要可操作的专业规范；教学指导委员会是全国高校的指导委员会，因该承担指导一般院校的任务；教育管理部门需要专业规范，作为依法检查教学质量的依据。

专业规范的作用是：分类指导学校的专业教学与建设工作，作为检查教学质量的依据。专业规范的性质主要是指导性，参照执行。有指导性内容，还有参考性内容。当与专业评估衔接时，专业规范的一些内容实际上就具有了规定性。规范对象是不同类型的专业教学，重点是规范一般院校的专业教学。也可以促进重点建设大学更加重视本科教学。

对专业基础课程的规范主要体现在基本要求上。基本要求可以理解为最低要求，低于这个要求就不能称之为合格的本科教育。其中的专业知识体系，可以理解为核心知识加可以选择性组合的非核心知识，少于核心知识，就不能算作这个专业的合格学生。然而，对基础课程的教学基本要求而言基本要求可以理解为最低课程质量标准。

2．电子电气基础课程教学基本要求制定的基本情况

上届电子电气基础课程教学指导分委员会在 2004-2005 年进行了两年的工作。本届基础课程教学指导分委员会自 2006 年以来又开展了 4.5 年的工作。参加这项工作的除了两届教学指导委员会成员外,还有前“课委会”的主任和特邀知名教授等数十人。

电子电气类课程的基础课程基本要求的制定按五个方向进行：电路分析、信号与系统、电磁场、电子技术、电工学。

基础课程教学工作进展情况如下：

1）2005 年 8 月 11-12 日基础课教指委在成都讨论研究，拿出了 5 个方向 12 门基础课程教学基本要求的修改稿；

2）2005 年 8 月 16-17 日兰州会议上向大教指委报告后，大教指委提出增加覆盖面广的专业平台课程。因此 2005 年 10 月 26 日在东南大学由基础课教指委牵头召开研讨会，增加了 “微机理”、 “数字信号处理”和“控制工程基础” 3 门平台课程和“集成电路设计基础”一门可选平台课程。

3）新一届教指委成立后，又根据教育部理工处的要求对电子电气 12 门基础课程基本要求进行了修改。4）2009 年第 11-12 期《教学指导委员会通讯》登载了 12 门基础课程基本要求。

3．电子电气基础课程教学基本要求内容举例

“电路分析基础”教学基本要求

1）地位、作用和任务

“电路分析基础”课程是高等学校电子与电气信息类专业的重要的基础课。学习本课程要求学生具备必要的电磁学和数学基础知识。电路分析基础课程以分析电路中的电磁现象，研究电路的基本规律及电路的分析方法为主要内容。电路分析基础课程理论严密、逻辑性强，有广阔的工程背景。通过本课程的学习，对树立学生严肃认真的科学作风和理论联系实际的工程观点，培养学生的科学思维能力、分析计

算能力、实验研究能力和科学归纳能力都有重要的作用。通过本课程的学习，使学生掌握电路的基本理论知识、电路的基本分析方法和初步的实验技能，为进一步学习电路理论打下初步的基础，为学习后续课程准备必要的电路知识。

2）基本内容与要求的理论教学部分包括：电路模型和电路定律； 电阻电路的分析； 动态电路的分析； 正弦稳态分析； 非正弦周期电流电路，而基本要求 实践教学部分包括：

会使用常用的仪器、仪表（如电压表、电流表、万用表、稳压电源、信号发生器、示波器等）；会应用常规的测试方法测量电压、电流、电功率等物理量和电阻、电感、电容等器件的参数，测定特性曲线；培养学生独立从事实验和初步的设计实验的能力，能分析并排除一些简单的故障，正确地读取和记录实验数据，绘制曲线；培养学生良好的实验习惯，树立实事求是和严肃认真的科学作风，根据实验数据和实验结果撰写实验报告，具有对实验结果进行分析和解释的能力；注意启发学生的创新思维，培养创新能力，安排综合性、设计性实验；了解一种电路分析软件，能用以求解电路分析基础课程的习题。

由此可见：“电路分析基础课程教学基本要求”是电路分析基础课程教学的指导性文件，是高等学校本科有关专业学生学习电路分析基础课程达到合格标准的最低要求，是学校组织本课程教学（制定教学大纲、计划，编写教材等）的主要依据，也是进行电路分析基础教学质量评估的重要依据；“电路分析基础课程教学基本要求”理论教学部分中的基本内容为要求学生理解、掌握的内容;“电路分析基础课程教学基本要求”只提出了教学内容的基本内容和可选内容，对于课程内容体系、教学方法、教学环节等，学校可以自主安排。亦可补充认为必要的以及新的内容，或按教学内容整合形成新的课程，以利于进行各种教学改革的尝试，形成各校的特色；在课堂讲授、实验课、习题课与课外练习等教学环节中，应注意贯彻理论联系实际的原则，并注意学生逻辑思维能力、工程观点和分析与解决问题能力的培养。根据本课程的特点，必须严格要求学生独立完成一定数量的习题。

4．工程教育专业认证

4.1 工程教育专业的目标

1）促进我国工程教育的改革，加强工程实践教育，进一步提高工程教育的质量；

2）建立与注册工程师制度相衔接的工程教育专业认证体系；

3）吸引工业界的广泛参与，进一步密切工程教育与工业界的联系，提高工程教育人才培养对工业产业的适应性；

4）促进我国工程教育参与国际交流，实现国际互认

4.2 工程教育专业认证标准

4.2.1 通用标准

1）专业目标中的专业设置

专业设置适应国家和地区、行业经济建设的需要，适应科技进步和社会发展的需要，符合学校自身条件和发展规划，有明确的服务面向和人才需求。包括：

(1) 专业设置的依据和论证明确充分，有相应学科作依托，专业口径、布局符合学校的定位。

(2) 学校根据经济建设和社会发展的需要、自身条件和发展潜力，确定在一定时期内培养人才的目标、层次、类型和人才的主要服务面向。

(3) 至少已有 3 届毕业生。

2）毕业生能力：专业必须证明所培养的毕业生达到如下知识、能力与素质的基本要求：

(1) 具有较好的人文社会科学素养、较强的社会责任感和良好的工程职业道德；

(2) 具有从事工程工作所需的相关数学、自然科学知识以及一定的经济管理知识；

(3) 掌握扎实的工程基础知识和本专业的基本理论知识，了解本专业的前沿发展现状和趋势；

(4 具有综合运用所学科学理论和技术手段分析并解决工程问题的基本能力；

(5) 掌握文献检索、资料查询及运用现代信息技术获取相关信息的基本方法；

(6) 具有创件，促进教师素质持续提升。注重培养青年教师，有专业教师队伍的进修、科研和发展规划；注重对教师的教学方法培训，以提高教学设计和教学过程的质量。

专职教师必须有足够时间和精力投入到本科教学中，并承担学生指导工作。 教师在很好的完成教学任务的基础上应该从事一定的工程实际问题研究。

3）支持条件

(1) 费：教学经费有保证，总量能满足教学需要。

(2) 施： 教室、实验室、实习和实训基地和相关设施在数量和功能上满足教学需要，管理规范。与企业合作共建实习和实训基地，在教学过程中为学生提供参与工程实践的平台。

(3) 资源：具备满足教学科研所必须的计算机、网络条件以及图书资料等。能够满足学生的学习以及教师的日常教学和科研所需，资源管理规范、共享程度高。

(4) 结合：具有稳定的校企合作伙伴，吸引企业积极参与专业的教学活动，提供工程实践条件，在人才培养过程中发挥较好的作用。

(5) 学生发展新意识和对新产品、新工艺、新技术和新设备进行研究、开发和设计的初步能力；

(6) 了解与本专业相关的职业和行业的生产、设计、研发的法律、法规，熟悉环境保护和可持续发展等方面的方针、政策和法津、法规，能正确认识工程对于客观世界和社会的影响；

(7) 具有一定的组织管理能力、较强的表达能力和人际交往能力以及在团队中发挥作用的能力；

(8) 具有适应发展的能力以及对终身学习的正确认识和学习能力；

(9)具有国际视野和跨文化的交流、竞争与合作能力。

4) 课程体系的课程设置

课程设置要服务于专业培养目标、满足预期的毕业生能力要求。课程体系设计有企业或行业专家参与;课程结构比例科学合理;人文社会科学类课程（含外语）约为总学分安排的 15%；数学与自然科学类课程约为总学分安排的 15%;工程基础类课程、学科专业基础类课程与专业类课程约为总学分安排的 40%;实践环节和毕业设计（论文）约为总学分安排的 25%。而课程体系中的实践环节包括：设置完善的实践教学体系。学校除在校内开展实践教学外，还要与企业合作，开展实习、实训，为学生提供参与工程实践的机会，使学生在自主、动手、综合、实验和创新能力等方面得到一定的锻炼。

5）师资队伍中的师资结构及教师发展

具有满足本专业教学需要的教师数量和符合学校现状和可持续发展所需要的教师整体结构；有适当比例具有工程经历的专职教师，有一定数量的企业或行业专家作为兼职教师。教学人员必须明确他们在专业质量提升过程中的责任。学校要为教师发展提供机会和条

(1) 能够保证较多数量与较高质量的生源。

(2) 毕业生在就业市场具有较强竞争力；社会和用人单位对毕业生的评价较高；毕业生去向与本专业的培养目标基本吻合。

(3) 指**导**：具有完善的学生学习指导、职业规划、就业指导、心理辅导等方面的措施并能够很好地

执行落实。能够为学生搭建良好的科技创新活动和社会实践平台，鼓励广大学生积极参与。

6）管理制度

(1) 教学制度： 必须具有保障教学运转的组织机构及人员，专业教学管理文件和规章制度完备，并能严格贯彻执行。各类档案文件管理规范，人才培养方案（培养计划）符合专业培养目标，各门课程的教学大纲、教材等科学、合理、完整，并能够根据实际情况及教学质量评价及时更新。

(2) 过程控制与反馈：建立严格的教学过程质量监控体系。各主要教学环节有明确的质量要求，通过课程教学和评价方法促进毕业生能力的实现；定期进行课程体系设置和教学质量的评价；及时反馈评价的结果；有不断改进和提高的内部机制。

7）质量评价

(1) 内部评价：专业必须证明建立适宜的机制，定期对专业培养目标及其达成度进行校内评价，其中应包括学生对课程和学习的反馈。学校、教师、学生应对专业培养目标和质量有较高的认可度。

(2) 社会评价：毕业生、用人单位对专业培养目标和质量有较高的认可度。专业的社会评价较好，具有一定社会影响力。主要包括社会对该专业人才的需求，社会舆论对该专业的反映，就业单位、学生继续深造的研究生培养机构对该专业毕业生情况的评价。

(3) 持续改进：专业具有比较完备的毕业生跟踪反馈体系。必须证明专业培养目标定期评价的结果用于本专业系统和持续的质量改进

5．结论

通过上述简略论述表明：中国高等教育的教学改革，正在不断地向纵深发展。为了使中国高等教育办学质量逐步进入国际一流大学的水平，制订了一系列的课程教学体系的基本要求与工程教育专业论证的标准。促使中国的高等教育逐步与国际的高等教育接轨，培养适应中国国民经济发展的高级专门人才。

作者简介

王志功　男，教授，博士生导师，东南大学射频与光电集成电路研究所所长。主要从事以砷化镓工艺为主的超高速,微波和毫米波集成电路,光电集成电路设计，设计出上百种集成电路，创造并保持多项世界纪录。

MULTIMEDIA SERVICES OVER WIRELESS INTERNET WITH DATA AGGEGATION

LU JIAN-HUA, XING TENG-FEI, DENG HUI, TAO XIAO-MING

Department of Electronic Engineering, Tsinghua University

Beijing 100084, China

lujh@wmc.ee.tsinghua.edu.cn

Abstract: This paper proposes a data aggregation scheme over wireless Internet for efficient multimedia services. The proposed architecture supports aggregate broadcasting of multimedia services according to user behaviors in wireless Internet. The service requirements from various users are aggregated by sufficiently utilizing the similarity of content demands in time and space and inherent delay tolerance in multimedia service deliveries. Specifically, two service aggregation schemes are proposed in time and space respectively. It is demonstrated that the proposed framework may provide quite improved spectrum efficiency that is critical to wireless Internet.

Keywordst: Data Aggregation; Wireless Internet; DelayTtolerance; Broadcasting

1. Introduction

During the last decade, wireless Internet has emerged as a promising way to provide multimedia services to mobile users and devices. Wireless Internet enables mobile email access, Web searching and even multimedia streaming possible from smart phones and roaming mobile computers. Furthermore, wireless Internet services have been available for years but are now becoming easier to find and more affordable. Wireless Internet services are based on Wi-Fi, WiMax, cellular and other state-of-the-art technologies. For example, it is expected that multimedia traffic will exceed voice traffic in wireless cellular networks soon. Meanwhile, multimedia service with a high data rate and low cost has become a goal for wireless Internet.

With efficient wireless transmission technologies, such as OFDM[1], MIMO[2], and Turbo coding [3], the frequency efficiency has been greatly improved. However, the cost of multimedia service is extremely high in wireless internet due to great bandwidth requirements. On the other hand, the data transmission with broadcasting technology costs low. For broadcast services, the video/audio data will be broadcast to all users only once, saving much bandwidth especially compared with unicast services, for which the data need to be transmitted N times for N users even if they require the same data.

The effort to add broadcast/multicast support to 3G networks dated back to 2002 when 3GPP started adding broadcast/multicast service to GSM/WCDMA. This work item is called Multimedia Broadcast and Multicast Service (MBMS). The specifications of MBMS were functionally frozen in 2004/2005[4] and the advanced version of MBMS, Evolved Multicast Broadcast Multimedia Service (eMBMS), was defined in Release 9 of the 3GPP specifications[5]It is no doubt that MBMS will be included in IMT-advanced system.

To date, most research on broadcast/multicast focuses on transmission methods such as those for mobile TV and audio-video conferencing[6]. Suh and Mo [7]showed that the multicast capacity would be saturated as the user number increases. Accordingly, they proposed a subcarrier/bit allocation method for multicarrier multicast services to support high throughput and proportional fairness among users. Kim et al.[8] proposed a resource

allocation scheme in an OFDM multicast system with focus on minimizing power consumption. Likewise, the video coding technologies like layered video coding[9]or scalable video coding [10] provide different broadcast/multicast video qualities according to the user channel bitrates. Jiang et al.[11] proposed an MBS (Multimedia multicast and broadcast service) architecture for mobile WiMAX to enhance service quality.

However, in wireless Internet, a great amount of multimedia services are provided to users by unicasting way. Because of the cost advantage of broadcast/multicast schemes, utilizing them in common unicast services will further improve spectrum efficiency with reduced bandwidth consumption. In order to further exploit the benefit of broadcast/multicast technology, this paper proposes a new wireless data communication system architecture, called Aggregate Data Broadcasting System (ADBS), which takes advantage of the broadcast/multicast technology incorporating user behavior.

The proposed ADBS is out of our awarded national basic research program in China (973), i.e., multi-domain collaborative broadband wireless communication, which commenced in 2007[12]. The multi-domain refers to service domain, resource domain, and user domain, etc. Specifically, the ADBS aggregates multimedia services in time and space domains according to service requirements and user behaviors, while aggregated services are delivered with multicast/broadcast for quite improved spectrum efficiency.

The rest of the paper is organized as follows. Section 2 proposes a framework of ADBS over wireless Internet. Accordingly, Section 3 presents two types of aggregate services, including aggregation in time/space domains. Finally, Section 4 concludes the paper.

2. Framework of ADBS over Wireless Internet

The main idea of the ADBS is providing multimedia services to multiple users in a broadcasting way. To achieve this, user behavior in time and space, as well as, the similarity of content demands from multiple users, different aggregation schemes for data broadcasting should be considered. Also, the aggregated services should be delivered by adaptive broadcasting supporting heterogeneous terminals and different channel conditions. By doing so, users still get the services they expect on time with acceptable quality, with no perceptible change in the method by which the service used to be provided. In the meantime, the system could notably improve the user experience and the user volume with the help of aggregate data broadcasting. The proposed framework of ADBS over wireless Internet is shown in Figure 1.

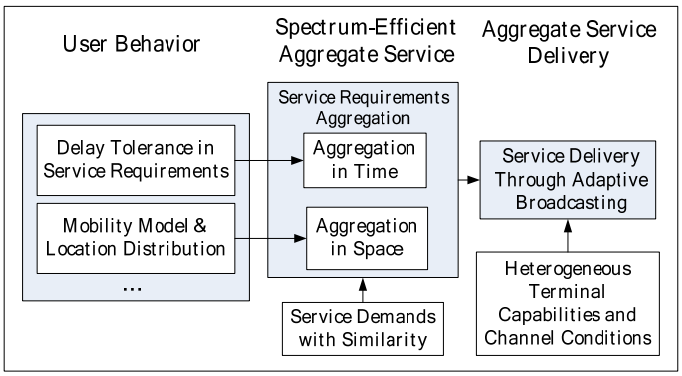

Fig 1 Framework of ADBS over wireless Internet.

In Figure 1, user behavior refers to delay tolerance in service requirements, mobility model and location distribution, etc., which are important factors affecting service models. By analyzing the various behavioral attributes of users in a system, the relationship between user behaviors and service models may be obtained. The similarity in content demands can be exploited to reduce resource consumption as long as properties of user behavior are well known and utilized, and then data broadcasting may be properly designed and implemented.

Several components of user behavior may include:

1) User habits in application experiences, such as distribution of total duration of each communication session, frequency of access, distribution of location and mobility model during each session, distribution of rate and quality requirements of service, distribution of preferred service types, and most often contacted communication partners, etc [13].

2) Personal relationships among users.

3) Total resource consumption of each communication session.

4) Inherent delay tolerance in service demands with respect to real-time transmission.

The most important part of the framework is multimedia service aggregation with different times and locations of requests. When services have some inherent delay tolerance, the base station may have the option to hold the requests for a certain time period, gather requirements for the same content from several users, and broadcast the message only once. This is the basic idea behind aggregation in time. Traditionally, these services are provided by unicast, which has rather low spectrum efficiency.

Likewise, in a cellular system with multiple cells, the same content for different users in different cells is often transmitted through unicast or separate broadcast in each cell. This again suffers a low spectral efficiency method. The same content demands may be aggregated and broadcast only once when the user behavior information, such as mobility and location distribution models, is known at base stations. With this information, base stations may carry out broadcasting when users from several cells gather in its communication range.

After the aggregations are implemented, data broadcasting still faces a major challenge with desirable adaption towards different terminal attributes including channel condition and processing capability. For instance, wireless networks are typically characterized by a wide range of channel qualities and receiving devices. The varying channel conditions result from the different locations of a varying number of users. The variety of devices with different capabilities range from cell phones with small screens and restricted processing power to high-end PCs with high-definition displays. These heterogeneities pose limitations for broadcasting configurations when trying to provide the aggregated service to the terminals. As such, aggregated service delivery technology for broadcasting is also included in Figure 1.

3. Aggregate Services Based on Broadcasting over Wireless Internet

As mentioned above, ADBS is to change the way of point-to-point multimedia services possibly to the way of point-to-multipoint by the use of inherent broadcasting property of wireless Internet. Mobile TV and alert messages are mostly broadcast oriented, thereby all users getting the same content at the same time without any specific requirements. On the other hand, the statistics from an operator in China show that more than 60% of networks' service loads are arbitrary downloads (Figure 2)[14]..

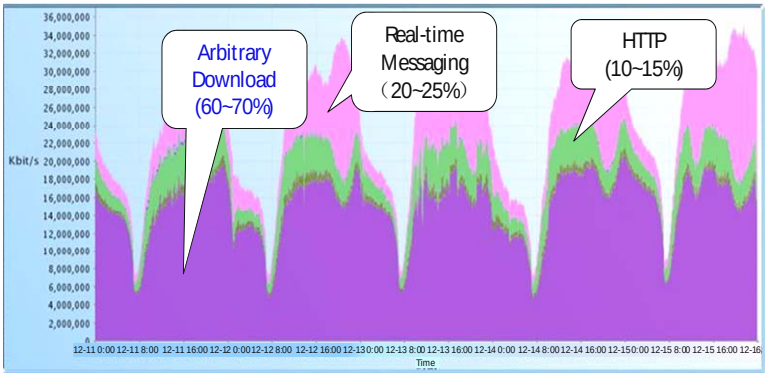

Fig 2 Throughput distribution of an arbitrary port of an operator in China

which maybe potentially serviced by the way of point-to-multipoint if the similarity of content demands can be utilized by sending those data in an aggregate broadcasting way instead of unicast. For example, statistics gathered from the website www.sina.com show that 10% of the point-to-point content downloads during a 30 minute time period, fall on the hottest news item. It is demonstrated that the bandwidth consumption can be decreased 80% as long as 20% of the most requested information is provided through broadcasting [15]

The goal of the ADBS system is to provide high spectrum efficiency and wide area coverage to a large number of users, and improve system capacity and data access rate under high traffic load conditions. In the sequel, we will show the basic principle of aggregation schemes in time and space, as well as their potential in improving spectrum efficiency.

3.1 Aggregation in Time

The data demanded by multiple users in an interval of time can be aggregated and broadcast to the users in order to save wireless bandwidth. The users' data communication cost will be then decreased greatly if they share information with the same spectrum.

The services likely have some inherent delay tolerance. This gives the base station the ability to hold the requests a certain time period, gather requirements from several users for the same content, and then broadcast the message only once. Figure 3 illustrates an aggregation in time domain.

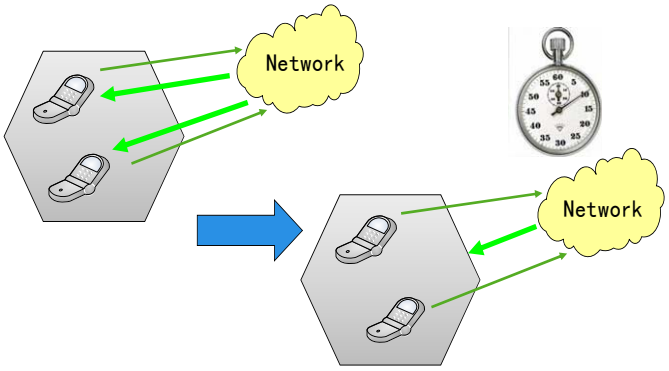

Fig 3 Aggregation data broadcast in time.

As an example, consider a single cell with 100 users and assume that there are 1000 items of information or service provided to the users in the cell. The item arrival process for each user is modeled as a Poisson process with mean arrival rate a=0.5 (item/slot). The slot duration can be set according to the service model. For this example, we assume a uniform probability distribution for each user's request item. The required bandwidth for transmitting any item to any user is assumed to be the same. Figure 4 shows the ratio of the bandwidth required by the broadcasting method of aggregation in time over the traditional unicast method.

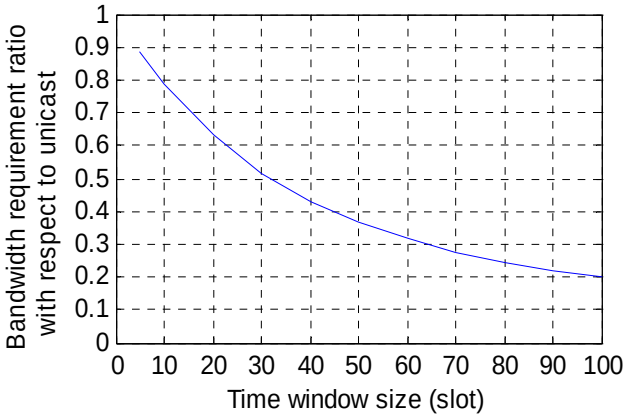

Fig 4 Bandwidth requirement ratio using aggregation in time under different time window sizes.

It is found that the bandwidth required ratio reduces gradually when increases the aggregation time window size. Here the time window size is the time period that the base station holds the request, and is set according to the delay tolerance of services. When the time window is set to 20 slots, we can save nearly 40% of bandwidth by using the aggregate in time method compared to the traditional unicast method. Note that the delay will increase with the length of aggregation time window. Also, there is a tradeoff between the bandwidth requirement and wait delay.

The uniform probability distribution in the example above may not be realistic since users often request "hot" items. To investigate this, we introduce three non-uniform density curves (see Figure 5).

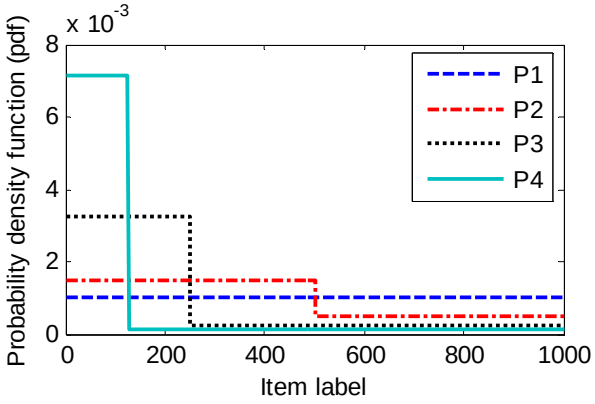

Fig 5 Probability density function of the arrival item.

In Figure 5, P1 refers to the uniform probability distribution of users' request item while P2, P3, and P4 indicate that the request hot items are concentrated on the first 500, 250, and 125 items, respectively. Figure 6 shows the resulting bandwidth requirement ratios for a time window size of 10 slots. It is observed that the bandwidth requirement ratio decreases significantly when user requests are focused on fewer hot items. Compared with the situation when the probability density function (pdf) of arrival item is P1, the bandwidth requirement decreases about 50% when the pdf of arrival item is P4.

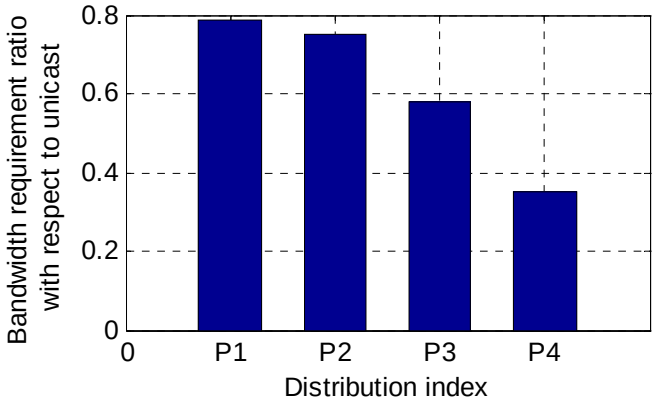

Fig 6 Bandwidth requirement ratio using aggregation
in time under different arrival item pdfs.

3.2. Aggregation in Space

Figure 7 illustrates the transition to aggregation in space.

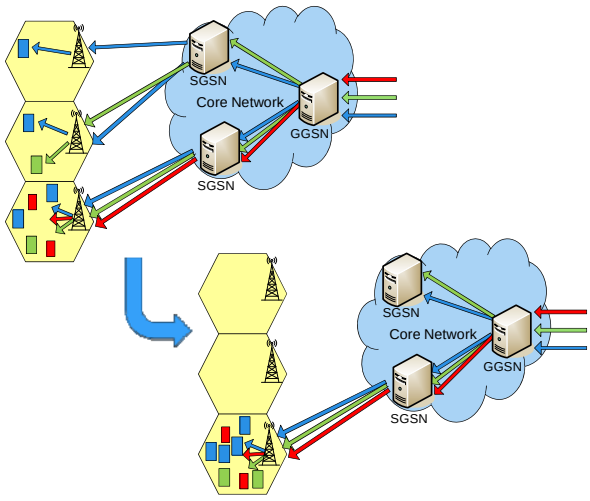

Fig 7 Aggregation data broadcast in space.

When an event that causes users to congregate in certain cells occurs, service demands in these cells may require the same content, with some inherent delay tolerance. Without aggregation in space, the same content for different users in different cells is transmitted through unicast or separate broadcast in each cell. Whereas with

aggregation in space, the base station can broadcast the message after several users with

the same content demand move into its coverage area. This method of aggregation requires that the base station knows the mobility model of users so that the base station may properly allocate resources according to the predicted locations of users. This process may potentially reduce resource consumption and yield higher spectral efficiency of the system.

To illustrate the advantage of aggregate data broadcasting in space, consider four adjacent cells in Figure 8.

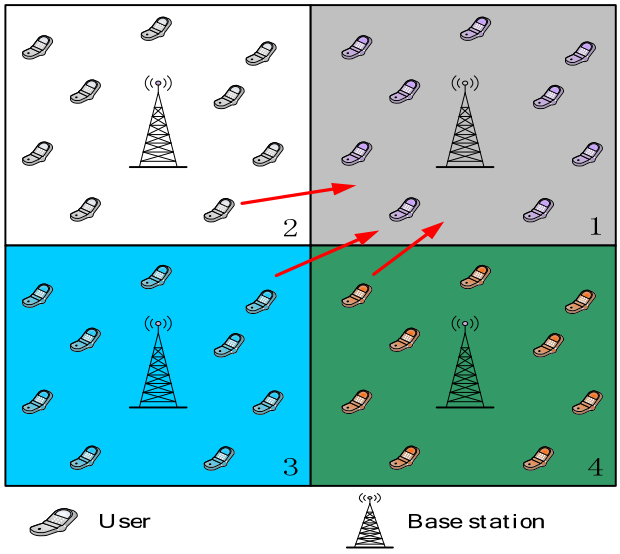

Fig 8 A 2×2 cellular system with square shaped cells.

The square coverage area of the cell is convenient for analysis and reasonable for network simulations [16] Each cell is assumed to be 1km×1km, and to initially comprise 50 uniformly distributed users. These users will move, in turn, towards a certain spot in the first quadrant cell. There are several state-of-the-art human mobility models based on statistics of real user traces and analytical fittings [17,18]. These models can reproduce mobility patterns of humans and are helpful in simulations and performance analysis.

Since the mobility patterns of outdoor users have features close to Levy Walks [19], we use the Levy-walk (LW) mobility model [20] to emulate user mobility. In the LW model, the total movement of a user consists of multiple steps. Each step is represented by four parameters, step length (l), direction (θ), motion time (Δt_f) and pause time (Δt_p). Here, l and Δt_p approximately follow inverse power law distributions. The moving speed is decided by a relationship between step length and motion time: $\Delta t_f = k l^{1-\rho}$, where $\rho = 0.79$ and $k = 18.72$ when $l <$ 500m. Adjusting k results in different average moving speeds. Moreover, θ follows a uniform distribution between 0 and 90^o for a conditional random walk towards the first quadrant cell. This assumption has some deviation from realistic scenarios since users may move backwards during the trip, yet it does not affect our analysis principally.

There are 1000 items of information or service assumed to be provided to the users in the cell. The item arrival process for each user is modeled as a Poisson process with mean arrival rate a=0.5 (item/second). Likewise, a uniform probability distribution for each user's request item is included in the simulation. The

required bandwidth for transmitting any item to any user is assumed to be the same.

According to [18], mobility models reflect social contexts among people who are sharing common interests or customs. These social contexts include:

1) Gathering: different people visit the same places during daily lives;

2) Regularity with spontaneity: each person often keeps a daily routine of going to the same place, yet with a few irregular visits to other places.

These contexts show that people do not randomly choose where to visit and when to do so. Accordingly, the average user moving speed is a key parameter in setting up the proper mobility model. Therefore, LW model may bring out the unique performance feature of our space aggregation mechanism with proper parameter settings, especially the setting of the direction θ and the average moving speed. For example, when most users are moving towards a same destination area, the degree of user aggregation will increase when the moving speed gets higher. This means that when the aggregation time window is fixed, more users will move to the same area covered by a single base station with a higher moving speed, thereby more service requests from different users can be aggregated. Figure 9 shows simulation results of the relationship between user moving speed and bandwidth consumption.

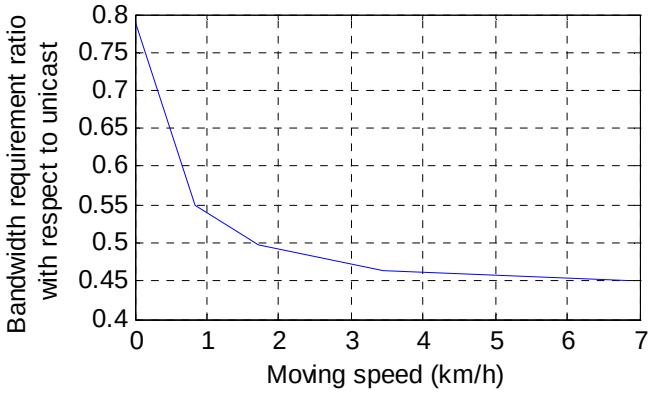

Fig 9 Bandwidth requirement ratio using aggregation in space under various average user moving speeds.

We find that the bandwidth requirement ratio reduces gradually when increasing the moving speed. When the moving speed is set to 3.5km/h (regular walking speed), we can save more than 50% of bandwidth by using aggregation in space compared with the traditional unicast method.

4. Conclusions

In this paper, a data aggregation-broadcasting framework for wireless Internet is presented. User behavior is included to exploit the similarity of the common unicast service requirements from various users in content demands, request time and space. Accordingly, two aggregation data broadcast schemes, aggregation in time and space, are proposed. Sample examples show that the aggregation in time and in space may save the bandwidth requirement significantly, which is quite promising to be applicable to wireless Internet.

Acknowledgement

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ON THE DESIGN OF HYBRID MULTIPLE ACCESS FOR DOWNLINK CHANNEL

JIAO BING-LI, MA MENG, WILLIAM C.Y. LEE

Advanced Institute of Communication ,Peking University

Beijing 100084, China

iaobl@pku.edu.cnj

Abstract：For increasing spectrum efficiency in a broadband mobile system, we develop a hybrid multiple access (HMA) technique applying on Comb-Spectrum CDMA (CS-CDMA) which combines OFDM, CDMA and TDMA in one system, for realizing a single-frequency seamless-coverage cellular system. In the cell structure, we proposed that the HMA system uses OFDM in the inner cell of each cell to provide high data rates for the mobile units near the base station and uses CDMA at the outer cell of each cell for the mobile units to combat inter-cell-interference (ICI) from their signals. To explore the potential of applying CS-CDMA, we developed a new method, called orthogonal cell codes (OCC), to nullify the ICI from neighboring cells. Also we integrate TDMA into the system for saving the bandwidth consumed by the pilots. Because deploying a broadband HMA system can take all advantages of a full OFDM system, we show how CS-CDMA can compensate the weakness of OFDM by suppressing the ICI in a statistic manner and avoid the complicated calculations using the scheduling methods over the OFDM sub-carriers. For testing the spectrum efficiency of this approach, a simulation has been carried out. The simulation results show much better performance from HAM system in comparison with that from LTE. Finally, to realize a HMA system, the major parameters of designing a HMA system have been given in this paper.

Key words：HMA;CS-CDMA;OFDM,OCC;LTE

1. Introduction

The requirement of a fourth generation (4G) system has been specified by ITU to provide ubiquitous and seamless broadband wireless services with high spectrum efficiency and low system complexity. 4G will have broader bandwidth, higher data rates, smoother and quicker handoff in providing voice-, data- and video service with respect to high quality of services. In the present literature, the authors are trying to find a reasonable solution to achieve high spectrum efficiency by including OFDM, CDMA and TDMA in a system for utilizing advantages of having each of them and compensating the shortcomings from each other as explained below.

OFDM has been chosen as a key technique of 4G due to the lower complexity of its equalizers in dealing with the large delay spread channels, and a better utility in providing high data rates[1~2]. In addition, the use of sub-carrier structure enables the radio resources scheduling methods and the simple implementation of MIMO that can increase the system capacity effectively [3~4]. A family of OFDM systems has been successfully shown in the wireless LANs, such as WiFi and WiMAX, delivering broadband Internet services. However, to use full OFDM systems in scenarios of seamless coverage from cell to cell can face challenges of strong ICI due to the sub-carrier to sub-carrier interference, and the scheduling methods do not solve the problem when a desired mobile suffers from fast fading channel or low signal to interference-plus-noise ratio (SINR) at cell edge.

On the other hand, spread-spectrum techniques, traditional used for anti-interference and anti-jam [5], have been well developed for code division multiple access (CDMA) systems that can suppress the ICI in a statistic manner [6]. Actually, the use of voice intermittence behaviors allows a reduction in the number of active codes

cannels at 3/8 [7] and, thus, supports a SINR gain more than 3 dB [8]. The success of CDMA in winning the competitions over third generation (3G) of mobile communication lies in the fact that it can utilize the same (entire) spectrum to cover the traffic in all cells with high system capacity and achieve reliable handoffs across the cells [9~10]. Actually, the capacity is interference limited, rather than the bandwidth limited as found in the other systems including OFDM systems. Moreover, in a network deployment, the use of spreading spectrum can provide relative stable signal powers at receivers. Thus, the system performance is found very robust [11].

However, applying the conventional CDMA to broadband transmission systems has been failed due to the strong self-interference problem, which needs very complicated techniques, e.g. using multi-user-detection to solve it [12].

Though CDMA was hanging-up its applications to the next generation system due to its multiple access interference (MAI), we need to reconsider it as long as 4G systems still require to work with a spread spectrum (single frequency) signal coverage and a voice service. In fact, several new CDMA techniques have been developed, such as MC-CDMA, CP-CDMA, and CS-CDMA [13~15]. All of them allow MAI free or quasi-free with help of zero forcing equalizer or MMSE equalizer, respectively. Further, an attempt of combining OFDM and MC CDMA has been published for the use in Down Link (DL) channels, thereby a mobile station (MS) uses MC CDMA near the Base Station (BS) and uses OFDM at cell edge [16]. However, this proposed access scheme is found mismatching the advantages of the CDMA and OFDM, since the CDMA does not help the use of entire spectrum to seamless coverage and the OFDM operates, essentially, on frequency reuse scheme that requires a larger bandwidth of spectrum in the network deployment.

To address the above mentioned problems, we develop a hybrid multiple access (HMA) technique applying on CS-CDMA to combine OFDM and TDMA for increasing the spectrum efficiency of broadband mobile systems. The CS-CDMA helps the use of entire spectrum to cells' coverage with assistance of a new technique, called orthogonal cell code (OCC) to nullify the ICI from contiguous cells. The reason of using CS-CDMA can be found for its simplicity of hardware implementation and high efficiency of obtaining diversity effects making it superior to the three new CDMA schemes mentioned above. In the system design, CS-CDMA code forms a comb shape of a CDMA signal in the frequency domain and allows the OFMA signal to be inserted into the gap of the comb spectrum. These two different spectrum structures are mixed together, however, maintaining their orthogonal property. Therefore, no interference between these two signal structures will occur over a DL channel when a mobile is in static state. In the system operation, the HMA uses OFDM in the inner cell of a cell to provide high data rates near the base station and uses CDMA to combat ICI at the cell edge of a cell. In addition, we integrate TDMA into the system for saving the bandwidth consumed by the pilots. Finally, we develop a new synchronization and pilot codes, which enable the signal processing to be free from the ICI that is from the contiguous cells, due to the use of zero correlation zone (ZCZ) codes [17].

The proposed techniques introduce in this study are primarily to solve the ICI problem in view of cellular structure. Some advanced techniques, e.g., adding MIMO technique are not precluded in the basic design of HMA, but do not include in this paper due to the limitation of the length of the paper. The description of the paper is organized as follows. Section II shows advantage of CS-CDMA with assistant of OCC for nullifying the ICI causing from contiguous cells. The system of combining CS-CDMA and OFDM is developed in section III,

and the integration of TDMA in the system is explained in section IV. Finally, the new designs of synchronization codes and pilot codes as well as some of the system parameters are presented in section V.

In the paper, the notation *K, N,* N', *J,* l, *n,* n', *i , j* and ξ are integers and the upper-scriber "*" denotes the conjugate operation.

2. CS-CDMA with OCC's assistance

In order to explain the role of CS-CDMA in a HMA system, we introduce, first, CS-CDMA [3] and the orthogonal cell code (OCC) technique, then, explain how they work together in suppressing the ICI by using a statistical approach.

2. 1. Brief review of CS-CDMA

Let define a conventional code vector, $\tilde{C}_k$, with its component, $\tilde{c}_k[\beta]$, as the mother code, where $\beta = 0,1,2,...K-1$ denotes the chip index of the code. There exists *K* orthogonal mother codes indexed by $k = 0,1,2,\cdots,K-1$.

By repeating a mother code for *N* times in time domain, we construct a repeated code vector, C_k, with *M* = *KN* in length. The component can be expressed by

$$c_k[i] = \sum_{n=0}^{N-1} \tilde{c}_k[i-nK], \quad \text{for } i = 0,1,2,..M-1 \tag{1}$$

with the condition $\tilde{c}_k[\beta] \equiv 0$ for $\beta < 0$ or $\beta > K-1$.

The 0th group codes can be obtained by grouping the *K* orthogonal codes as described in (1). By adding a Cyclic Prefix (CP), we complete the construction of the 0th group of CS-codes in form of $C_k^{(0)}(i)$ with the components of $c_k^{(0)}(i)$ expressed by

$$c_k^{(0)}(i) = \begin{cases} c_k^{(0)}(i+M-L_{cp}) & 0 \le i \le L_{cp}-1 \\ c_k^{(0)}(i-L_{cp}) & L_{cp} \le i \le M+L_{cp}-1 \end{cases} \tag{2}$$

where L_{cp} is the length of the CP in number of chips.

The other (*N*-1) groups can be obtained by shifting the first group codes in frequency domain sequentially with a frequency space $\Delta f_n = 2\pi n / KN$ for *N=1,2,..N-1.*

The physical insights of CS-CDMA can be shown in Fig.1 with the following explanations.

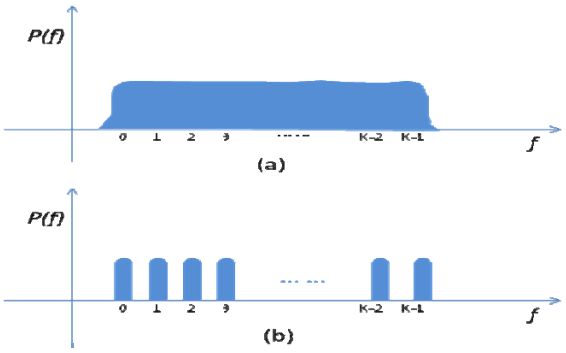


Fig.1 The spectrum of conventional CDMA and CS-CDMA;(a) the spectrum of conventional CDMA ,(b) the Comb spectrum of CS-CDMA.

By assuming chip duration T_c, one can find, in Fig.1(a), that the baseband bandwidth of conventional CDMA is $W_c = 1/T_c$. Repeating a CDMA code, i.e., the mother code, for *N* times in time domain will divide the spectrum into K sub-carriers with equal frequency space $\Delta f = \frac{1}{NT_c}$. The shape of comb spectrum is formed with each sub-carrier bandwidth of

$$B_s = \frac{W_c}{KN} = \frac{1}{KNT_c} \tag{3}$$

where B_s is bandwidth of the sub-carrier (see Fig. 1(b)).

It is noted that the bandwidth of the sub-carrier of CS-CDMA can be accommodated rather freely by adjusting *N*.

By using CS-codes to generate code channels, the design of CS-CDMA signals is complete. In the operations, the transmitted signal can be expressed in chip level by

$$s(i) = \sum_{n=0}^{N-1} \sum_{k=0}^{K-1} d_k^{(n)} c_k^{(n)}(i) \tag{4}$$

where $s(i)$ is the transmitted signal and $d_k^{(n)}$ is the information symbol. The letters i, n and k are the indices of chip sequence, group number and code channel, respectively.

By removing the CP from the signals, the receiver uses the hopping accumulator in time domain to separate the 0[th] group from the others at the receiver [15]. The separated signals are formed in a circular convolution between the channel and the mother codes expressed by

$$r^{(0)}(\beta) = \sqrt{N} \sum_{l=0}^{L-1} \sum_{k} h(l) d_k^{(0)} \tilde{c}_k^{(0)}(\beta)[< \beta - l >_K]$$

$$\text{for } \beta = 0,1,2,...K-1 \tag{5}$$

where $r^{(0)}$, β, $h(l)$ and $d_k^{(0)}$ are the signal of 0th group, chip sequence, the channel gain factor of the lth path in time domain, and the information symbol of kth code channel in 0th group, respectively, and $<\cdot>_K$ denotes modulo operation.

The nth group signals can be separated in the same way of using the above hopping accumulator after we move the group to the position of 0th group in frequency domain.

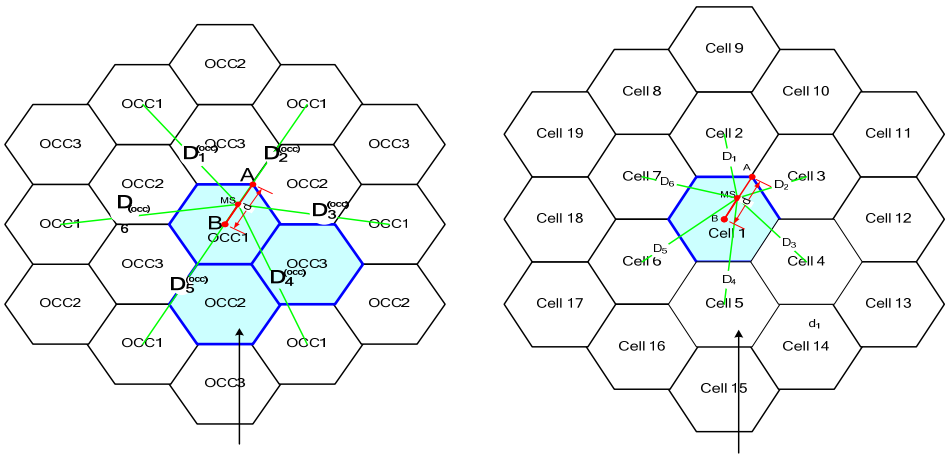
2. 2. OCC method for CS-CSDMA

It is a motivation to find ways to nullify ICI in a cell caused from the contiguous cells, we develop a method of using orthogonal codes to assign codes to cells in a cluster. We define J orthogonal codes as orthogonal cell codes (OCC) to be used in a cluster of size J, where J = 3,4,7, or 11. The OCC can be expressed in vector, $\mathbf{c}_j^{(occ)}$, with components of $c_j^{(occ)}(\xi)$, where $\xi = 0,1,..,J-1$. The orthogonality is expressed by

$$\left\langle \mathbf{c}_j^{(occ)} \middle| \mathbf{c}_{j'}^{(occ)} \right\rangle = \sum_{\xi=0}^{J-1} c_j^{(occ)}(\xi) c_{j'}^{(occ)^*}(\xi) = \begin{cases} 1 & j = j' \\ 0 & j \neq j' \end{cases} \tag{6}$$

where $\langle \cdot | \cdot \rangle$ denotes inner product operation, and j and ξ indicate the cell and symbol sequence, respectively. The method of using OCC in a general case can be found in appendix A.

Let us temporally assume that CS-CDMA uses entire spectrum to cover each of the cells in the cellular system. We choose J=3 in applying OCC to make full-code channels of the groups of CS-CDMA, i.e., each of the group uses full code channels. The cellular diagram is plotted as shown in Fig. 2(a). The ICI nullification for a general case is derived in Appendix A. By sacrificing the bandwidth efficiency of 1/3, the SIR can be increased significantly. Then, in a burst type of the transmissions, CS-CDMA can take the advantage of reducing the number of code channels, i.e., the number of the active channels (like that appeared in voice communication) from the interfering cells as shown in Fig. 2(a).



（a） A Cluser（J=3）
(a) OCC in cluster of J =3,

(b) A Cluser（J=3）
(b) conventional case of CDMA.

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Fig.2. The diagram ICI

Without losing generality, we need consider only the 0th group in the application of OCC, because it can be separated from the other group in frequency domain and each of the other groups can be converted to the form of the 0th group. Assuming that the mobile channel can be modeled by a block fading channel with a length of three symbol durations in the bock, the transmitted signals of *j*th cell can be expressed by

$$y^{(j)}(\xi,i) = c_j^{(occ)}(\xi)s^{(j)}(i)$$

$$\text{for} \quad \xi = 0,1,2,\cdots \tag{7}$$

with $s^{(j)}(i) = \sum_{k=0}^{K-1} d_k^{(0)(j)} c_k^{(0)(j)}(i)$, where $y^{(j)}(\xi,i)$, $c_j^{(occ)}(\xi)$ and $s_k^{(j)}$ are the transmitted signal, the OCC code and the signal of CS-CDMA of 0th group of the *j*th cell, respectively. $d_k^{(0)(j)}$ and $c_k^{(0)(j)}(i)$ are the information symbol and the CS-code of the 0th group in the *j*th cell, respectively.

Assuming that the signal transmissions of all cells are synchronized at chip level, the ICI causing from the same group in the contiguous cells can be nullified by the use of OCC as described in Appendix A. The signals of the desired cell, e.g. j' th cell, can be separated chip by chip as

$$r^{(j')}(\beta) = \sqrt{N}\sum_{l=0}^{L-1}\sum_{k} h_{j'}(l_{j'})d_k^{(0)(j')}(0)\tilde{c}_k^{(j')}(\beta)[<\lambda - l_{j'}>_K] \tag{8}$$

which can be used in the signal processing of CS-CDMA for the demodulations [15].

Now, we take the nearest interfering cells into account to calculate the SIR for a MS traveling along the line from point A to B (see Fig. 2(a)) by

$$SIR^{(OCC)} = \frac{1}{\sum_{i}^{6}(d / D_i^{(occ)})^4} \tag{9}$$

where $SIR^{(OCC)}$, *d* and $D_i^{(occ)}$ are the *SIR* measured at the MS, the distance between the mobile and its BS, and the distance between the MS and *i*th interferencing cells.

The numerical results of (13) are shown in Fig. 3,

in which we make a parallel comparison between SIR of (13) and with a conventional CDMA with loading factor of 1/3 in an environment of Fig. 2(b). The results of the conventional CDMA are marked by $SIR^{(Con)}$, which are calculated by substituting in Fig. 2(b) for $D_i^{(occ)}$ in (13) with a multiplication of de-spreading gain, *G*=3, to SIR. In view of the results of the both, one can find that OCC method can achieve $SIR_1 = 11.5dB$ at the cell edge, while the de-spreading of the conventional CDMA can achieve only 1.76 dB.

When the MS goes closer to the center of cell, the *SIR*s of both go up and the difference of the two becomes slight less in comparison with that at cell edge, as found in the curve of $SIR^{(OCC)} - SIR^{(Con)}$

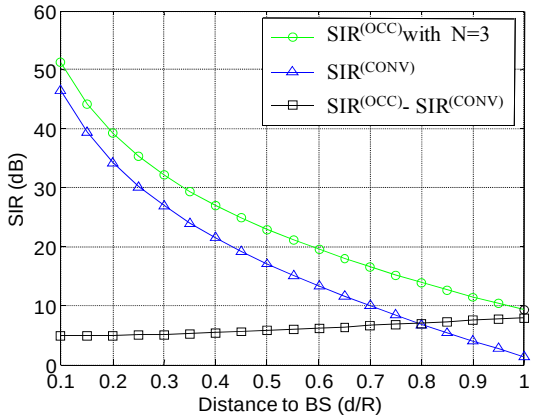

Fig. 3. Comparison of SIR between the CS-CDMA with OCC and the conventional CDMA.

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Though the above results are obtained based on long-term large scale path loss model, they are good approximations without taking short-term fading into account. It is because the broadband channel can have the bandwidth much greater than that of coherency bandwidth. The ergodic nature applies to some extent and mitigates the short-term fading.

3. Combination of CS-CDMA and OFDM

In this section, we will introduce a method of combining CS-CDMA and OFDM in a single carrier. The role of CS-CDMA assisted by OCC is to provide seamless coverage and that of OFDM is to provide high data rates around BS in the inner cell.

To construct a CS-CDMA and OFDM combined system, we construct the sub-carrier bandwidth and CP of the CS-CDMA signals equal to that of OFDM signal. A portion of groups of CS-CDMA is used and the OFDM sub-carriers are inserted into frequency vacancies of CS-CDMA. Considering of matching the standard format of LTE, we construct the OFDM into sub-carrier blocks, each of which has 12 consecutive sub-carriers as shown in Fig.4.

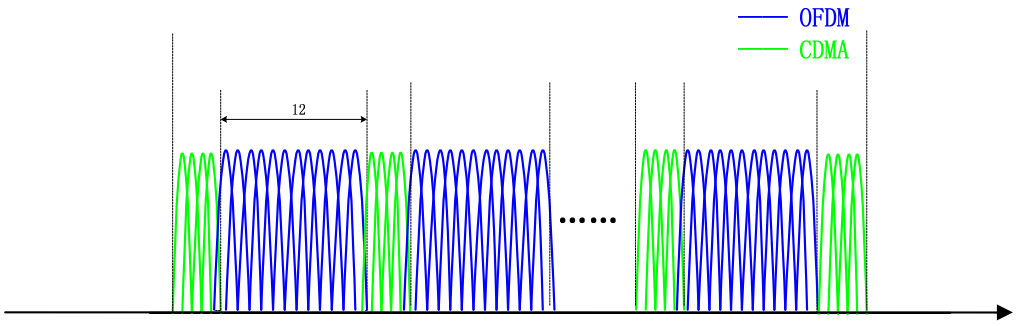


Fig.4. Spectrum of CS-CDMA&OFDM; the green curves show the spectrum of CS-CDMA and the blue the OFDM.

We name the combined system as “CS-CDMA&OFDM”.

Because the bandwidth occupation of one group of CS-CDMA is actually 1/*N* of the total system bandwidth, there is no bandwidth efficiency loss when we use a full-load operation in the group, i.e. loading the *K* channels, which allows the symbol rate to be $R_s = (1/KN)K = 1/N$.

In the system operation, we divide a conventional cell into two layers; (1) inner cell and (2) outer cell as shown in Fig.5.

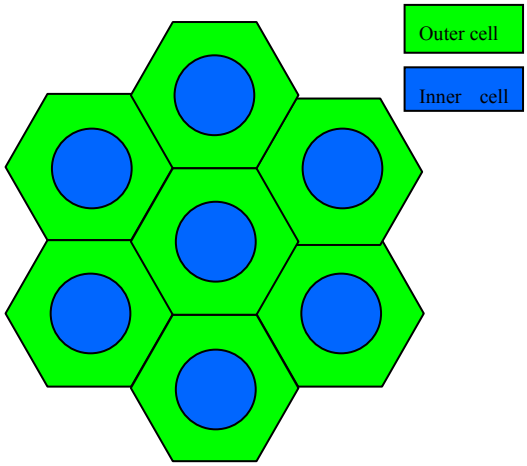


Fig. 5. The inner cell and outer cell depicted in the cells.

The mobile should access to OFDM system when it is in the inner layer cell and access to CDMA system when it is in outer cell. The spectrum structure of all cells is exactly the same, where the signals of CS-CDMA are modulated by OCC of *J=3,* for nullifying the ICI causing from the contiguous cells. The signals of the OFDM are modulated in the same way as that of LTE. Actually, this design enables the OFDM to gain *SIR* by the distance isolation among the inner cells of different cells. Finally, the geometric location strategy does not preclude the voice traffic to be allocated to CS CDMA in both layers.

For maintaining a traffic connection during a call, an intra cell handoff is needed between inner- and outer cells, and an inter-cell handoff is needed between the outer cells of two cells. Because the inter-cell handoff is taken between two CDMA signals, soft handoff can be applied as it does in the conventional CDMA systems.

Now, we compare the CS-CDMA&OFDM system to that of a full OFDM system, e.g. LTE. Actually, we need only to compare the performance of CS-CDMA with that of OFDM, because the performance of running OFDM signal in CS-CDMA&OFDM system should be not much different from that of LTE, even in case that of using the scheduling methods. As mentioned above, the role of CS-CDMA is to combat the ICI. We compare the two systems for the achievable spectrum efficiencies near the cell edge. The channel model of Extended TU6 is used in both systems for the channel simulations. In LTE system, we map the *SIR* values to the channel quality information (CQI) as specified in the LTE standard.

The simulation results have shown the achievable spectrum efficiency at a given BER = 10^{-3}. The MS of CS-CDMA uses a MMSE receiver to process the signals and the MS of LTE. Assuming that both receivers have

delivered channel information properly, we obtain the achievable spectrum efficiency of CS-CDMA from the simulation results. The spectrum efficiency is even slightly larger than 0.2 bps/Hz at cell edge, i.e. d/R = 1 (see Fig.2). In comparison, we find that LTE can only be operable up to *d/R*= 0.8, where the notations *d* and *R* are the distances between BS and MS and that of the cell radius in Fig. 2, respectively. At *d/R* = 0.6, the spectrum efficiencies of both are near 0.4 bps/Hz as shown in Fig. 6.

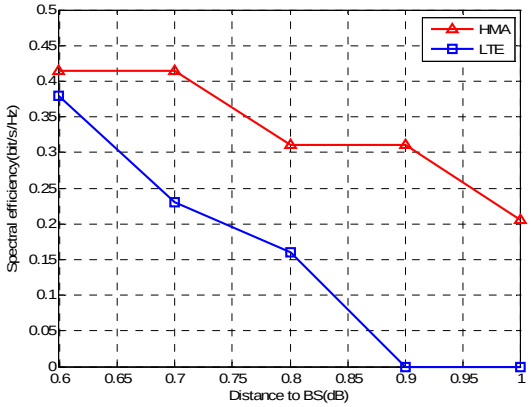


Fig.6. The comparison of spectrum efficiencies between CS-CDMA with OCC and LTE.

The above results indicate that the CS-CDMA with OCC can achieve much higher spectrum efficiency than LTE in the spread spectrum coverage environment, when no other radio resource scheduling method has been used. This is often the case being used in low SIR or/and fast moving users.

4. Integration with TDMA

The motivation of integrating TDMA into HMA is for saving the bandwidth consumption of pilot channels.

Let consider a time multiplexing pilot design with a focus on time interval between two pilots. As being well described in [18~19], the time interval should be within the coherent time of the user's channel

$$\Gamma_c \approx \lambda / v \tag{10}$$

where Γ_c is coherent time, *v* is speed of the MS and λ is wavelength of the carrier. It is obvious that the larger the speed the mobile moves, the shorter the coherent time appears. For supporting high mobility, the conventional system constructs the time interval according to the highest speed, e.g. 360km/h, and, thus, adopts the shortest coherent time of all users. In a sub-carrier system, the bandwidth efficiency of the pilots can be calculated by

$$\eta_p = 1 - \psi_p \tag{11}$$

with

$$\psi_p = (m_s / m)(T_s / \Gamma_c) \tag{12}$$

where η_p represents the bandwidth efficiency, ψ_p is the bandwidth reduction factor due to the

consumption of pilots, m and m_s are the number of total sub-carriers and that of the sub-carriers occupied by the pilots respectively. T_s and Γ_c are the time spacing between pilot symbols and coherent time, respectively. To support fast fading channel with smallest coherent time can increase the bandwidth reduction factor or in other word, can reduce the bandwidth efficiency significantly. This low bandwidth efficiency problem has been raised in LTE design.

Actually, we should intuitively realize that the bandwidth in the conventional system design stated above has been over consumed, when we notice that not all users move at the highest high speed. Owing to save the bandwidth, we design the pilots' time interval based on a relative low speed, e.g. 120km/h, rather than the highest speed, i.e. 360k km/h. Thus, the bandwidth reduction factor expressed in (12) can be reduced to 1/3 in respect to the conventional design. Yet the new design can still support some of the users moving at the highest speed, i.e. 360km/h. by scheduling their transmitted information data to their positions close to the pilots in the time domain. The maximum number of the highest speed users can be, roughly, at 1/3 of total users. For those users who move at a lower speed, the BSs will schedule their information data to the positions relative far from the pilots as shown in Fig.7. We show the two designs, one is the conventional pilot design and the other is the proposed pilot design. The highest speed that users move is at 360km/h in two designs.

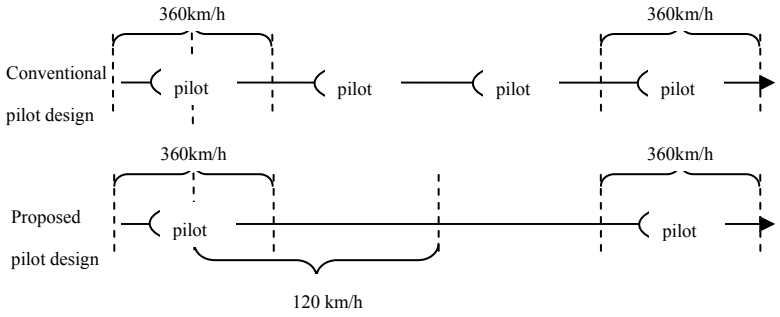


Fig.7. Two pilot designs are given: the above one is the conventional design and the lower one is the new proposed design.

Because of the dynamical arrangement of every user's information data at its transmitter, i.e. the information data of the various-speed users are placed in different distances to the pilots in the time domain, each receiver has to access those data in TDMA manner. Thus, we name this technique as TDMA when it is integrated into HMA. However, TDMA does not support the large number of users moving at highest speeds. Therefore it is a drawback of having TDMA integrated into HMA. Nevertheless, in reality this would not be the case.

5. HMA Design

Before presenting a HMA design in a system level, we introduce a new design of synchronization codes and that of pilot codes as explained below.

5.1. Synchronization code design

This subsection proposes a new synchronization code design aiming at combating ICI in HMA system. The synchronization of the DL signals requires finding the time- and frequency offset. As has been known, the synchronization accuracy is limited by the particular code design and the algorithm used as well [6~ 7].

In designing a synchronization code, we first select one zero correlation zone (ZCZ) code and repeat it in time domain twice as follows

$$\tilde{S}^{(j)}(\beta) = Z_j(\beta) + Z_j(\beta - N')$$

$$\text{for} \quad \beta = 0,1,2,..,2N' \tag{13}$$

where $Z_j(\beta)$ is the ZCZ code with $Z_j(\beta) \equiv 0$ for $\beta < 0$ or $\beta \geq N'$. N' is the length of the code, i.e. number of chips. The orthogonality of the codes can be expressed by

$$\sum_{n=0}^{N-1} Z_j(\beta) Z_{j'}^*(\beta + l)_{\bmod N'} = \begin{cases} 0 & i \neq i' \\ N' & i = i' \end{cases} \tag{14}$$

with $-L_{free} \leq l \leq L_{free}$ where l and L_{free} are the relative delay and 1/2 length of the free window[17] respectively . An interesting question may be raised for what is the number of the ZCZ codes available to our synchronization code design. We give the answer in Appendix B.

Secondly, by adding a CP to the ZCZ code described in (13), we complete the synchronization code design

$$\tilde{S}^{(j)}(n') = \begin{cases} \tilde{S}^{(j)}(n'+N'-L_{CP}) & 0 \leq n' \leq L_{CP} - 1 \\ \tilde{S}^{(j)}(n'-L_{CP}) & L_{CP} \leq n' \leq 2N'-1 \end{cases} \quad \text{For}$$

$$n' = 0,1,,2..,2N'+L_{CP-1} \tag{15}$$

Now, we work with a cell cluster of size *J* and assign different synchronization codes to different cells in the cluster. In addition, we assume that all BSs transmit synchronously the synchronization codes. The channels linking between the BSs and the MS does not vary in the duration of a synchronization code. The received synchronization signals at a MS can be written as

$$y_s(n) = \sum_{j=0}^{J-1} \sum_{l} h_j(l) S^{(j}(n-l) + n_0 \tag{16}$$

with $h_{j'}(n) \equiv 0$ for $n < 0$ or $n > L_{CP}$, where $h_j(n)$ and n_0 are the channel gain factor and the noise, respectively.

The time offset can be calculated by searching the maximum value of

$$\eta_t = \sum_{n}^{N-1} y_s(n) y_s^*(n - N') \tag{17}$$

and the frequency offset can be calculated by

$$\Delta f = \frac{1}{2\pi}\arg\left\{y_s(n)y_s^*(n-N')\right\} \tag{18}$$

where N' is the length of the ZCZ code.

The results of (17) and (18) give the time- and frequency offset. Then the MS uses the cross-correlation of ZCZ to identify the cells by

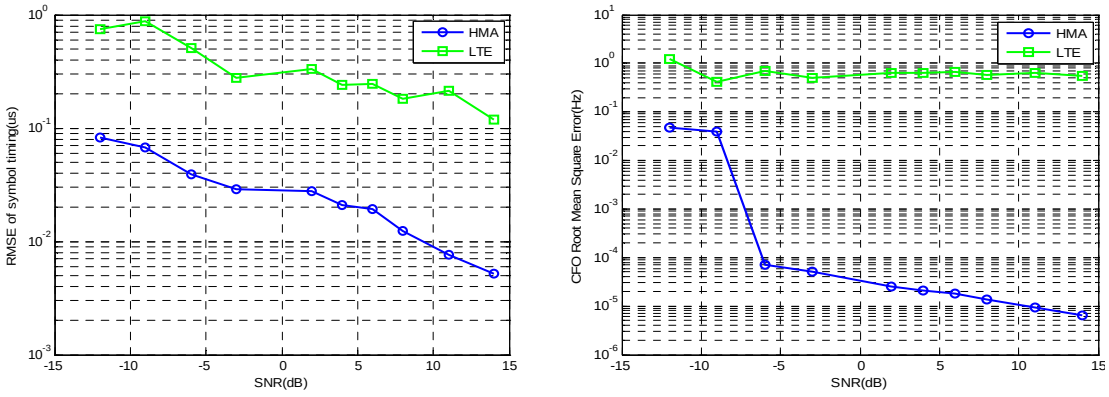
$$Y_{\max} = \max\left\{ \sum_{\chi=0}^{2N-1} y_s(\beta)\,\tilde{S}^{(j')^*}(\beta) \right\}$$

$$\text{for} \quad j' = 0,1,2,..J-1 \tag{19}$$

where $Y_{\max}$ indicates the desired cell.

It is noted that the result of (17) presents a time synchronization to ensure that the calculation of (19) can fall in the free window of the ZCZ code, and the calculations in a whole synchronization processing expressed in equation (17), (18) and (19) are free of ICI within the cluster of size J.

To test the performance of this new design in HMA system, we construct four synchronization codes, each of which is constructed by the ZCZ code having 1024 chips in length with the free window of 257 chips and CP of 257 chips. The simulation is done for using the four synchronization codes to a cluster of *J=4* cell in a 19-cell environment. The synchronization codes are assumed to be transmitted over a carrier frequency at 2GHz with a chip rate of 20.48Mchip/second. The long-term path loss is assumed in proportion to d_i^{-4}, where d_i is the distance between the *i*th BS and the desired MS. The fading channel is modeled by an extended TU6 channel. The accuracies of the proposed synchronization codes in HMA system are used to compare with that of a conventional synchronization in LTE system based on Root Mean Square Error (RMSE). The simulation results are shown in Fig. 8 (a) and (b) when a MS is in the position of Point A as shown in Fig. 2.



(a) shows the results of time offse (b) shows that of frequency offset.

Fig. 8. The comparison of accuracy between the proposed synchronizati
Method of HMA and the conventional synchronization method of LTE

In comparison with LTE, one can find that the accuracies of finding both the time offset and the frequency offset of HMA are much better than those of LTE.

5.2 Pilot code design

Channel estimation is a critical component in communication systems that uses coherent detection technique to process signals. In the HMA system design, we apply the ZCZ codes, as in the pilots, to support the channel estimation for MIMO of 4x4 in the DL channel. We use sixteen ZCZ codes, each of which has 2048 chips in length with free window of 129 chips and CP of 192 chips, to a cluster of 4-cell size. Thus, there is no any ICI within the cluster as long as the excess delay is smaller than 127 chip durations. The pilot codes are shown in Appendix C.

We use simulation method to test the performance of channel estimation with an assumption of perfect synchronization and same channel condition as stated in V.1. The channel gain factor is, first, estimated by the correlations of ZCZ codes in the time domain.,

$$\tau_k^{(j')} = \sum_{j=0}^{19} \sum_{l'}^{L_{ma}-1} [h_j(i-l_j)Z_j(j) + n_0][Z_{j'}^*(i+k)] \tag{20}$$

for $k = 0,1,2,...,128$ with $l_{j'} \equiv 0$ (because this assumes the perfect synchronization of time synchronization). Then, the channel estimates of (20) are transformed to frequency domain by using FFT. The accuracy of the channel estimates of HMA is compared, again, with that of LTE as shown in Fig. 9.

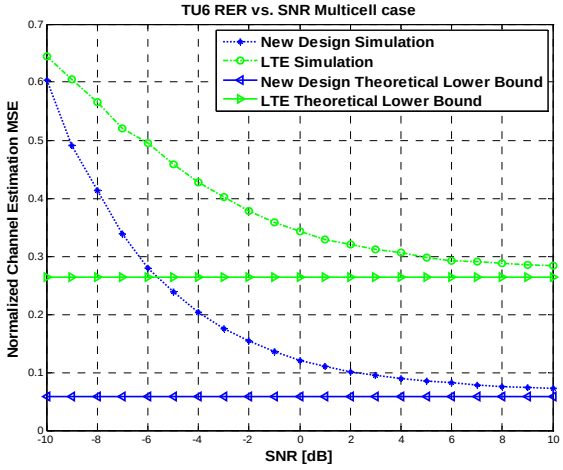


Fig. 9 Comparison between the new design of Channel estimation
of HMA and the conventional design of that of LTE.

One can find, again, much better results of root mean square error (RMSE) for HMA system.

5.3 HMA Design Parameters and Performance

The next generation mobile networks have been a vigorous topic research topic for last several years. The researchers are approaching to the common goal, i.e. the maximum data rate of 1Gbps for static users and that of 1Mbps for mobile users. They are working from two directions; (1) developing mobile network, primarily, for

voice communication with seamless coverage and (2) developing wireless network for Internet access (unnecessarily with seamless coverage). The former is required to support for a large number of users and the latter for high data rates. The HMA fulfill the performances by applying CDMA and OFDM in the two tasks which match the two directions mentioned above. CS-CDMA deals with ICI and, thus, provide a distance isolation for the OFDM system which allows OFDM works in a similar environment as that of wireless LAN. The design for achieving a ratio of CS-CDMA bandwidth to OFDM bandwidth is an issue to be discussed later because this relates to a complicated matter with the users and service types[20~21]. However, we present some parameters of physical layer of the system below to show the basic combinations of CDMA and OFDM in HMA system.

The digital bandwidth of the HMA system is 20.48MHz with its subcarrier bandwidth of 10 kHz. The CP is designed at 9. 375 μs . The spectrum of HMA is shown in Fig. 4 and the frame structure is shown in Fig. 10.

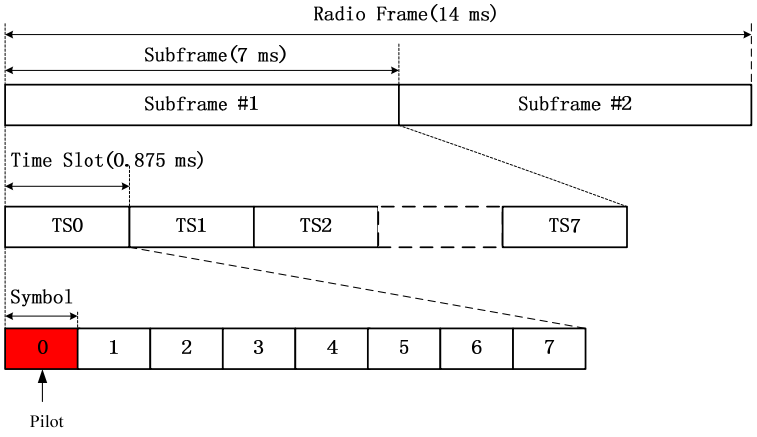


Fig.10. The diagram of HMA frame in time domain.

In considering the bandwidth reduction due to the effective format of CP, the more accuracy in getting time offset and frequency offset in synchronization code and the ingénious way to getting less consumption of time intervals of pilots, the HMA design has the bandwidth efficiency of 78% when it supports 4x4 MIMO.

6. Conclusion

This paper introduces a new HMA that combines CDMA, OFDM and TDMA on the purposes of combating the ICI problem, providing high data rates and saving the bandwidth. The following benefits are found in the HMA system in comparison with LTE system: (1) The use of CDMA is to explore its ability to reduce the ICI effects, especially in voice communication and allow the OFDM to work in an area, near BS, with a relative high SINR, (2) introducing TDMA in HMA can reduce the bandwidth consumption of pilots down to 1/3 and (3) the synchronization codes and pilots codes are designed to become ICI free from the neighboring cells. Finally, the system simulations demonstrate an advantage of using HMA at the cell edge because of its spectrum efficiency superior to LTE in that area. The new HMA system can be easily implemented and operable. The handover between cells can be done smoothly. A new orthogonal cell codes is used to nullify the ICI from the neighboring cells. Overall the new HMA system can help in regaining some weakness of LTE system.

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Appendix A ： Orthogonal Cell Codes

In the OCC (Orthogonal Cell Code) scheme, the time varying channel is assumed to be a block fading channel that does not vary in a block of *J* symbol durations and, however, varies block by block. An information symbol of a conventional system is transmitted over *J* symbol durations as modulated by its OCC as

$$x^{(j)}(\xi) = c_j^{(occ)}(\xi)s^{(j)}$$

$$\text{for} \qquad \xi = 0,1,..J-1 \tag{A-1}$$

By assuming that all cells of a cluster transmit the signals in synchronization and over the same frequency, we describe the OCC for both the flat- and selective fading channel as follows.

On a flat fading channel, the terminal receives the signals from *J* cells as a superposition of them,

$$\begin{aligned} y(\xi) &= \sum_{j}^{J-1} h_j x^{(j)}(\xi) \\ &= \sum_{j}^{J-1} h_j c_j^{(occ)}(\xi)s^{(j)} \end{aligned} \tag{A-2}$$

where h_j is the channel gain factor of the channel from the *j*th BS to the MS. The received signals from (A-2), for *J* cells, can be written as a vector as $\mathbf{y} = \{y(0), y(1),...., y(J-1)\}$. The signal of desired cell can be obtained by $\left\langle \mathbf{y} \middle| \mathbf{c}_{j'}^{(occ)} \right\rangle$ as

$$\begin{aligned} y^{(j')} &= \left\langle \mathbf{y} | \mathbf{c}_{j'}^{(occ)} \right\rangle = \sum_{\xi}^{J-1} y(\xi) c_{j'}^{(occ)*}(\xi) \\ &= \sum_{j}^{J-1} h_j s^{(j)} \sum_{\xi}^{J-1} c_j^{(occ)}(\xi) c_{j'}^{(occ)*}(\xi) = h_{j'} s^{(j')} \end{aligned} \tag{A-3}$$

where $y^{(j')}$ is the desired signal with *j'* denoting the desired cell.

In a frequency selective fading channel, the channel response in (A-2) becomes a vector with an excess delay, $h_j(l)$, $l = 0,1,2,..L_{CP}-1$ and $h_j(l) \equiv 0$ for $l < 0$ and $l > L_{cp}$, where L_{CP} represents the largest channel delay. In working with a broadband transmission system, we define a discrete modulation function, $f_\alpha^{(j)}(\beta)$, for the signal in the jth cell with $\beta = 0,1,2,..M-1$, to transmit the information symbols in parallel in time domain, e.g. with OFDM- and CS-CDMA transmission, at receiver. (Does it what you mean?) By using again the OCC scheme, the transmitted signals can be expressed as

$$x^{(j)}(\xi,\beta)=\begin{cases} c_j^{(occ)}(\xi)\sum_{\alpha} f_\alpha^{(j)}(M-L_{CP}+\beta)s_\alpha^{(j)} & \beta < L_{CP} \\ c_j^{(occ)}(\xi)\sum_{\alpha}^{N'-1} f_\alpha^{(j)}(L_{CP}-\beta)s_\alpha^{(j)} & \beta \geq L_{CP} \end{cases} \quad \text{(A-4)}$$

where $f_\alpha(\beta)$ is the modulation function, with β and α are the time- and the sub-carrier/code channel sequence respectively, and CP is found in (A-4) for $\beta < L_{cp}$.

By removing CP from the received signals, (A-2) can be written as

$$y\ (\xi,\beta)=\sum_{j=0}^{N-1}\sum_{l=0}^{L_{CP-1}} h_j(L_{CP}-l-\beta-l_j)c_j^{(occ)}(\xi)\sum_{\alpha} f_\alpha^{(j)}(\beta)s_\alpha^{(j)} \quad \text{(A-5)}$$

where $\beta = 0,1,2,..M-1$ is the time sequence marking the signal samples in time domain and *lj* is the relative signal delay to the desired cells.

We arrange the results of (A-6) by forming a vector for each given β as $\mathbf{y}(\beta)=\{y\ (1,\beta'),y\ (2,\beta'),....,y\ (J-1,\beta)\}$, and calculating $\left\langle \mathbf{c}_{j'}^{occ} \middle| \mathbf{y}(\beta) \right\rangle$ yields the signal of desired signal cell as

$$\begin{aligned} y^{(j')}(\beta) &= \sum_{\xi=0}^{J-1}\Big(\sum_{j=0}^{3}\sum_{l=0}^{L_{CP-1}} h_j(L_{CP}-l-\beta-l_j)c_j^{(occ)}(\xi)\sum_{\alpha} f_\alpha(\beta)s_\alpha^{(j)}c_{j'}^{(occ)^*}(\xi) \\ &= \sum_{l=0}^{L_{CP-1}} h_{j'}(L_{CP}-l-\beta)\sum_{\alpha} f_\alpha^{(j')}(\beta)s_\alpha^{(j')} \end{aligned} \quad \text{(A-6)}$$

where $y^{(j')}(\beta)$ is the signal of *j'th* cell, i.e the desired cell. It is noted that the valid of equation (A-7) holds as long as all excess delays are not larger than the length of CP.

The signals of desired cell can be fully recovered from (A-7) when the operation has been taken over $\beta = 0$ to $\beta = M-1$. Finally, as showing from the above analysis, the use of OCC can reduce the bandwidth efficiency by a factor of 1/*J* in most case. We choose a smaller J, *J*=3 for this application.

Appendix B： Construction of Synchronization Codes by Using Four Binary ZCZ Codes

According to [17], The construction of the binary ZCZ codes is restricted by

$$L = L_0 2^{2n+m-t} \quad M = 2^{n+1} \quad Z_{cz} = 2^{n+m-t} + 1 \tag{B-1}$$

where L and Z_{cz} denote length of the codes and length of zero correlation zone in number of chips respectively, and M is the number of the available codes. In the design of synchronization codes, we construct four ZCZ codes with length of 1024 chips, and each of the codes has a free window of 257 chips. The four synchronization codes are obtained by equation (17) based on the four ZCZ codes mentioned above, which are shown in Table B.

Table B ZCZ Codes of Length 1024

Code ID	ZCZ Codes of Length 1024
1	2EDED1DED121D1DED1212E21D121D1DE2EDED1DED121D1DED1212E21D121D1DE2EDED1DED121D1DE2EDED1DE2EDE2E212EDED1DED121D1DE2EDED1DE2EDE2E21D1212E212EDE2E212EDED1DE2EDE2E212EDED1DED121D1DED1212E21D121D1DED1212E212EDE2E21D1212E21D121D1DE2EDED1DED121D1DE2EDED1DE2EDE2E21
2	7B8B848B8474848B84747B748474848B7B8B848B8474848B84747B748474848B7B8B848B8474848B7B8B848B7B8B7B747B8B848B8474848B7B8B848B7B8B7B7484747B747B8B7B747B8B848B7B8B7B747B8B848B8474848B84747B748474848B84747B747B8B7B7484747B748474848B7B8B848B8474848B7B8B848B7B8B7B74
3	D1212E212EDE2E212EDED1DE2EDE2E212EDED1DED121D1DED1212E21D121D1DED1212E212EDE2E21D1212E21D121D1DE2EDED1DED121D1DE2EDED1DE2EDE2E212EDED1DED121D1DED1212E21D121D1DE2EDED1DED121D1DE2EDED1DE2EDE2E212EDED1DED121D1DE2EDED1DE2EDE2E21
4	84747B747B8B7B747B748474848B7B8B848B8474848B84747B748474848B7B8B848B8474848B7B8B848B7B8B7B747B8B848B8474848B84747B748474848B84747B747B8B7B7484747B748474848B7B8B848B8474848B7B8B848B7B8B7B747B8B848B8474848B84747B 8B848B8474848B7B8B848B7B8B7B74

Appendix C： Construction of Synchronization Codes by Using Sixteen ZCZ Codes

As can be restricted by (B-1), we construct sixteen ZCZ codes, each of which 2048 chips in the length and 129 chips in free window. The are shown in Table C.

Table C：ZCZ codes of Length 2048

Code ID	ZCZ Codes of Length 2048
1	2EDE2EDE2EDE2EDE2EDE2EDE2EDE2EDE2E212E212E212E212E212E212E212E21D1212ED ED1212EDED1212EDED1212EDED1DE2E21D1DE2E21D1DE2E21D1DE2E21D121D1212EDE2 EDED121D1212EDE2EDED1DED1DE2E212E21D1DED1DE2E212E212EDED121D1212EDE2E DED121D1212EDE2E21D1DED1DE2E212E21D1DED1DE2E21D121D121D121D1212EDE2EDE 2EDE2EDED1DED1DED1DED1DE2E212E212E212E212EDED1212EDED121D1212EDED1212 EDE2E21D1DE2E21D1DED1DE2E21D1DE2E212EDE2EDED121D121D121D1212EDE2EDE2E 212E21D1DED1DED1DED1DE2E212E21D1212EDE2EDED1212EDED121D1212EDED1DE2E2 12E21D1DE2E21D1DED1DE2E21
2	7B8B7B8B7B8B7B8B7B8B7B8B7B8B7B8B7B747B747B747B747B747B747B747B7484747B8B 84747B8B84747B8B84747B8B848B7B74848B7B74848B7B74848B7B74847484747B8B7B8B847 484747B8B7B8B848B848B7B747B74848B848B7B747B747B8B847484747B8B7B8B847484747B 8B7B74848B848B7B747B74848B848B7B7484748474847484747B8B7B8B7B8B7B8B848B848B8 48B848B7B747B747B747B747B8B84747B8B847484747B8B84747B8B7B74848B7B74848B848B 7B74848B7B747B8B7B8B847484748474847484747B8B7B8B7B747B74848B848B848B848B7B747B7 484747B8B7B8B84747B8B847484747B8B848B7B747B74848B7B74848B848B7B74
3	D1212EDED1212EDED1212EDED1212EDED1DE2E21D1DE2E21D1DE2E21D1DE2E212EDE2 EDE2EDE2EDE2EDE2EDE2EDE2EDE2E212E212E212E212E212E212E212E212EDED121D121 2EDE2EDED121D1212EDE2E21D1DED1DE2E212E21D1DED1DE2E21D121D1212EDE2EDED 121D1212EDE2EDED1DED1DE2E212E21D1DED1DE2E212E212EDED1212EDED121D1212ED ED1212EDE2E21D1DE2E21D1DED1DE2E21D1DE2E21D121D121D121D1212EDE2EDE2EDE2 EDED1DED1DED1DED1DE2E212E212E212E21D1212EDE2EDED1212EDED121D1212EDED1 DE2E212E21D1DE2E21D1DED1DE2E212EDE2EDED121D121D121D1212EDE2EDE2E212E21 D1DED1DED1DED1DE2E212E21
4	84747B8B84747B8B84747B8B84747B8B848B7B74848B7B74848B7B74848B7B747B8B7B8B7B 8B7B8B7B8B7B8B7B8B7B8B7B747B747B747B747B747B747B747B8B847484747B8B7B8 B847484747B8B7B74848B848B7B747B74848B848B7B74847484747B8B7B8B847484747B8B7B 8B848B848B7B747B74848B848B7B747B747B8B84747B8B847484747B8B84747B8B7B74848B7 B74848B848B7B74848B7B7484748474847484747B8B7B8B7B8B7B8B848B848B848B848B7B74 7B747B747B7484747B8B7B8B84747B8B847484747B8B848B7B747B74848B7B74848B848B7B7 47B8B7B8B847484748474847484747B8B7B8B7B747B74848B848B848B848B7B747B74

5	D121D1212EDE2EDED121D1212EDE2EDED1DED1DE2E212E21D1DED1DE2E212E212EDED121D1212EDE2EDED121D1212EDE2E21D1DED1DE2E212E21D1DED1DE2E212EDE2EDE2EDE2EDE2EDE2EDE2EDE2EDE2E212E212E212E212E212E212E212E21D1212EDED1212EDED1212EDED1212EDED1DE2E21D1DE2E21D1DE2E21D1DE2E212EDE2EDED121D121D121D1212EDE2EDE2E212E21D1DED1DED1DED1DE2E212E21D1212EDE2EDED1212EDED121D1212EDED1DE2E212E21D1DE2E21D1DED1DE2E21D121D121D121D1212EDE2EDE2EDE2EDED1DED1DED1DED1DE2E212E212E212E212EDED1212EDED121D1212EDED1212EDE2E21D1DE2E21D1DED1DE2E21D1DE2E21
6	847484747B8B7B8B847484747B8B7B8B848B848B7B747B74848B848B7B747B747B8B847484747B8B7B8B847484747B8B7B74848B848B7B747B74848B848B7B747B8B7B8B7B8B7B8B7B8B7B8B7B8B7B8B7B747B747B747B747B747B747B747B7484747B8B84747B8B84747B8B84747B8B848B7B74848B7B74848B7B74848B7B747B8B7B8B847484748474847484747B8B7B8B7B747B74848B848B848B848B7B747B7484747B8B7B8B84747B8B847484747B8B848B7B747B74848B7B74848B848B7B74847484748474847484747B8B7B8B7B8B7B8B848B848B848B848B7B747B747B747B747B8B84747B8B847484747B8B84747B8B7B74848B7B74848B848B7B74848B7B74
7	2EDED121D1212EDE2EDED121D1212EDE2E21D1DED1DE2E212E21D1DED1DE2E21D121D1212EDE2EDED121D1212EDE2EDED1DED1DE2E212E21D1DED1DE2E212E21D1212EDED1212EDED1212EDED1212EDED1DE2E21D1DE2E21D1DE2E21D1DE2E212EDE2EDE2EDE2EDE2EDE2EDE2EDE2EDE2E212E212E212E212E212E212E21D1212EDE2EDED1212EDED121D1212EDED1DE2E212E21D1DE2E21D1DED1DE2E212EDE2EDED121D121D121D1212EDE2EDE2E212E21D1DED1DED1DED1DE2E212E212EDED1212EDED121D1212EDED1212EDE2E21D1DE2E21D1DED1DE2E21D1DE2E21D121D121D121D1212EDE2EDE2EDE2EDED1DED1DED1DED1DE2E212E212E212E21
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RESEARCH ON THE UBIQUITOUS WISDOM NETWORKS

Zhou Xianwei [1], Hu Jia-hui [1], WangChao[1], He Huan [2], He Feixiang [1]

1） Dept. of Communication Engineering, School of Information Engineering,
University of Science & Technology Beijing,
Beijing 100083, China;
xwzhouli@sina.com

2） Dept. of ECET, Southern Polytechnic State University, Marietta GA
30060-2896, America

Abstract-This paper describes the concept of ubiquitous wisdom networks (UWNs). First, we overview the development of the traditional intelligence-oriented ubiquitous networks and propose the UWNs. Then, the introduction of wisdom and the analysis of wisdom nodes in UWNs are outlined. And then, the architecture of UWNs is detailed.

Keywords-ubiquitous wisdom networks (UWNs)；wisdom；architecture

1. Introduction

The American scientist Mark Weiser proposed the concept of Ubiquitous Computing [1] in 1988, on which he did considerable researches[2~4] subsequently. Based on this concept, Korea and Japan put forward the concept of the ubiquitous network during 2004 to 2006, according to the needs of their IT development strategies. They insisted that the ubiquitous network society would behave as the technology social form which composed by the intelligent network, the most advanced computing technologies and other leading digital technologies. The aim of them is to build an environment full of computing and communications to mix people together gradually. Since then, the research and development of the ubiquitous network get worldwide attention. At present, the most representative cases are the u-Japan plan, u-Korea strategy, Singapore's Next Generation I-Hub plan and the u-Taiwan strategy of Taiwan, China.

Although the network services have been improved greatly at present, it only can be considered the quantity variance from the view of services quality. People can be satisfied only with ultimate services under the existing conditions [5]. With the proposing of the Smart Planet [6] by IBM in the January 2009, the idea of ubiquitous network attracts a strong attention once more with its 4U features - ubiquitous, unique, universal, and user-oriented. However, countries in the whole world have their own new directions for the research of the ubiquitous network today. For example, in July 2009, Japan developed a new generation of information technology strategy- i-Japan strategy of 2015. And the word i here contains two meanings: first, it means inclusion, that is, to make use of information technology like water and air; second, it means innovation. The Korea Communication Commission put in place the basic infrastructure construction planning of Internet of Things in October 2009, and turned to the development of Internet of Things, following the issue of the Internet of Things in 2020 - Roadmap for the future by the European Union in September.

Therefore, the traditional ubiquitous network which is based on intelligence can no longer meet the growing

demand for information of humanity. In this paper, we proposed ubiquitous wisdom networks (UWNs), in the network system of which, network-related parties will have a common goal, which is to increase the wisdom of networks. Through the introduction of the wisdom, UWNs will realize a high degree of unity among the academic research, technology development, equipment manufacturing, network operation and policy setting.

The rest of the paper is organized as follows: section 2 introduces the wisdom philosophy. In this part, we first introduce the concept of wisdom and then describe the definition of the wisdom node in UWNs. Subsequently, we develop the framework of UWNs in section 3, and three kinds of architecture are detailed. Finally, section 4 analyses some open issues and concludes this paper.

2. Wisdom philosophy

2.1 The concept of wisdom

First we should make it clear that wisdom is different from intelligence. This can be expressed as the following three aspects [5]. Firstly, the relationship between intelligence and wisdom is not including simply, because their abilities involve kinds of fields respectively. Secondly, they emphasis different aspects – intelligent emphasis the ability, while wisdom emphasis the perception. Thirdly, the objectives to be achieved are distinct – intelligence goes to the improvement and perfection, while wisdom is faced to surpass the boundary.

Generally, wisdom can be distilled from knowledge, knowledge can be derived from information, information can be gathered from data and finally data can be assembled, acquired, switched and channeled by the existing tools and techniques borrowed from computer science and network technology [7]. To a network, we conclude the process of the wisdom formation here as shown in Fig. 1.

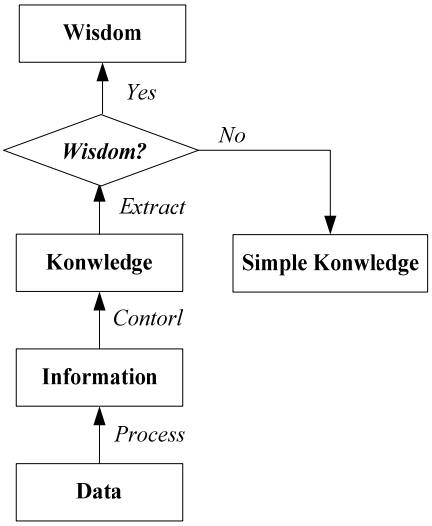

Fig.1 The process of the wisdom formation

In Fig. 1, wisdom is acquired as follows: first, the collected raw data is processed to information. Then, through controlling the information, we establish a credible and persuasive knowledge base (KB). Finally, wisdom extracted from the KB, and other knowledge with no wisdom we call it simple knowledge.

2.2 Wisdom nodes

The nodes in UWNs can be called wisdom nodes. According to the level of the wisdom that the node has, we classify four kinds of wisdom - Super Wisdom (SW), High-level Wisdom (HW), Mid-level Wisdom (MW) and Elementary Wisdom (EW). Then, four kinds of nodes are obtained, i.e. elementary wisdom nodes, mid-level wisdom nodes, high-level wisdom nodes, and super wisdom nodes. Nodes with different kinds of wisdom are distributed as the pyramid structure shown in Fig.2.

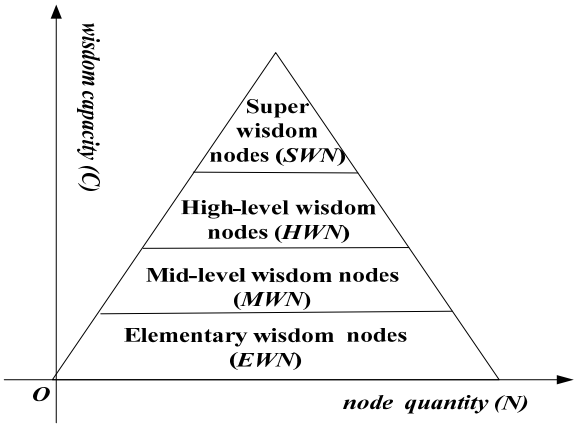

Fig.2 the structure of the wisdom nodes distribution

The EW is the basic wisdom that any nodes should possess while only very few nodes have SW. The wisdom amount of a node is unfixed during its lifetime. The node which has low level of wisdom can raise their wisdom capacity to a high level over time.

There are two extreme cases when wisdom is measured. The first case is that wisdom is infinite, and it corresponds to the probability of the inevitable occurrence event in the standard event field F , namely 1, and that is the case of SWN. The second case is that there is no wisdom, which corresponds to the probability of the event that is unlikely to occur in F , namely 0. The two extreme forms can be obtained from the definition, but in real life situations turn up between them.

3. The framework of UWNs

The framework of UWNs is shown in Fig.3 which is involved three constituent parts, i.e. the layer architecture, the abstract architecture, and the technological frame.

The front cubic side demonstrates the layer architecture of UWNs, and it consists of the application layer, wisdom layer, transport layer, network layer, data link layer and physical layer. We give the transport layer, network layer, data link layer and physical layer a joint name – general based layer. The layer between general based layer and the application layer is the wisdom layer. The function of each general based layer is similar to the according layer in traditional networks. The new layer – wisdom layer provides services that network wants. The wisdom layer is able to connect low layers, in DTNs [8], the wisdom layer is depicted as the bundle layer, and thus the application programs can achieve multi-regional inter-communication.

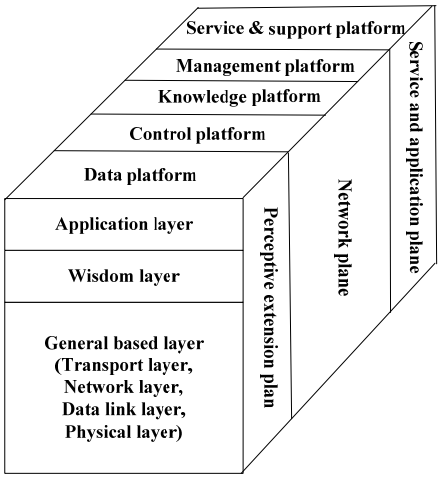

Fig.3 The framework of UWNs

The right one demonstrates the abstract architecture, and it consists of the perceptive extension plan, network plane and service and application plane. The main function of the perceptive extension plan is to realize information collection, capture and object identification. The network plane optimizes network features according to the perceptive extension plan, to support material-to-material and material-to-man or man-to-material communication well. The service and application plane is oriented to various applications. The task of this plan is to realize the information processing, collaboration, sharing and decision.

The upside demonstrates the technological frame, and it consists of the data platform, control platform, knowledge platform, management platform and service & support platform. In [9], the data platform, control platform and knowledge platform are described clearly. It depicted that the data plane concerns the basic data necessary for the localization process, the control platform is in charge of controlling data plane's entities in order to retrieve the necessary data, and the knowledge platform provides a global view of all information concerning the network. The management plane involves all management issues, such as mobility, task, security, etc. The service & support platform involves many fields, such as common middleware, information opening platform, cloud computing and service support.

As shown in Fig.3, there are some correlations between the abstract architecture and the technological frame. According to each architecture function, the data platform corresponds to the perceptive extension plan, control platform, knowledge platform and management platform correspond to network plane, and service & support platform corresponds to the service and application plane.

4. Conclusions

We have discussed UWNs which introduced wisdom in ubiquitous networks. The process of the wisdom formation and the definition of the wisdom node are detailed, and we classify four kinds of wisdom nodes -

SWN, HWN, MWN and EWN. By integrating three kinds of architecture into three different surfaces of a cube, and thus a good representation of the relationship among them obtained.

In the UWNs, many open research issues that need in-depth study inevitably exist certainly, such as the management of the wisdom nodes, technical issues of the network organization, routing and security problems.

Next, we will improve every aspect of UWNs, especially in its routing problem, and we will try to develop a variety of wisdom-oriented network.

Acknowledgement

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THE INFLUENCE TO TEACHING AND RESEARCH OF UNIVERSITY'S RELATED SUBJECTS BY FIELDBUS TECHNOLOGY AND THE CORRESPONDING SOLUTION

WANG YONG-HUA , JIANG HAO, AN XIAO-YU

Zhengzhou University of Light Industry and Key lab,of information electrical appliances of Henan province, Zhengzhou 450002, China

wyh@zzuli.edu.cn

Abstract: Firstly from two aspects of teaching and research analyses the extensive influence to university's related subjects by the development and popularized application of fieldbus technology. In the aspect of teaching, based on the curriculum changes of "Electrical Control Technology" course analyses the demands to curriculum system and lab construction and so on by new technology. In the aspect of research, discusses the opportunities for teacher's study and its application fields by fieldbus technology. At last from many aspects, such as curriculum configuration, the buildup of teaching book, special lab construction and the training mode for qualified personnel and so on gives out the detailed solutions, and analyses the successful practical experiences, provides useful references for the construction and development of related subjects.

Keywords: Fieldbus;Industrial network;reform on teaching; research;Specialities construction;;Engineering education;PROFIBUS

现场总线技术对高校相关专业教学和科研的影响及对策

王永华　江 豪　安小宇

郑州轻工业学院 河南省信息化电器重点实验室，河南 郑州 中国 450002

摘要：首先从教学和科研两大方面剖析了现场总线技术的发展和普及应用对高校相关专业所产生的广泛影响。在教学方面，基于电气控制技术课程的历史沿革，分析了新技术对课程体系、实验室建设等方面的要求；在科研方面，分析了现场总线技术为拓展教师科研及其应用领域所带来的机遇。最后从课程设置、教材建设、专业实验室建设、人才培养模式等诸多方面讨论了应对措施，并对成功的实践经验进行了总结分析，为相关专业的学科建设和发展提供了借鉴。

关键词：现场总线;工业网络;教学改革；科研;专业建设;工程教育;PROFIBUS

1. 引言

国际电工委员会在现场总线国际标准IEC61158中给现场总线下了一个定义[1]：安装在制造或过程区域的现场装置与控制室内的自动控制装置之间的数字式、串行、多点通信的数据总线称为现场总线。基于现场总线技术而实现的控制系统称为现场总线控制系统（Fieldbus Control System，FCS）。现场总线技术的串行连接体系结构，一举克服了并行连接的许多不足；在技术上，它成功解决了开放竞争和设备兼容两大难题，实现了现场设备的高度智能化、互换性和控制系统的真正分散化，现场总线给工业自动化应用技术领域带来的变化是“革命性”的。仅以在工业自动化领域应用最广泛的PROFIBUS现场总线技术为例，据ARC的白皮书报告[2]，由于PROFIBUS 可实现紧密链接工厂自动化和过程自动化的集成解决方案，

据统计，到2009年底全球安装了超过3100万台PROFIBUS总线设备，其中超过540万用于过程工业。现场总线技术已经渗透到了电气控制系统的各个角落。

现场总线技术的发展和普及应用对工科院校的教学和科研产生了较大影响。高等院校和其密切相关的专业主要有：电气工程及其自动化、自动化、电力系统及其自动化、电子信息科学与技术、机械设计制造及其自动化、测控技术与仪器等专业。在新形式下如何进行教学改革，更新科研方向，如何培养出符合技术进步要求的创新型工程技术人才，都是必须解决的课题。

2. 对教学的影响

现场总线技术的发展对高校相关专业教学的影响主要体现在课程设置和实验室建设等方面。

2.1 相关课程的历史沿革

电气控制技术是受影响最大的课程，以其为例简单讲解一下相关课程的历史沿革。高校电类专业“电气控制技术”课程近 30 年的发展变化情况如图 1 所示。

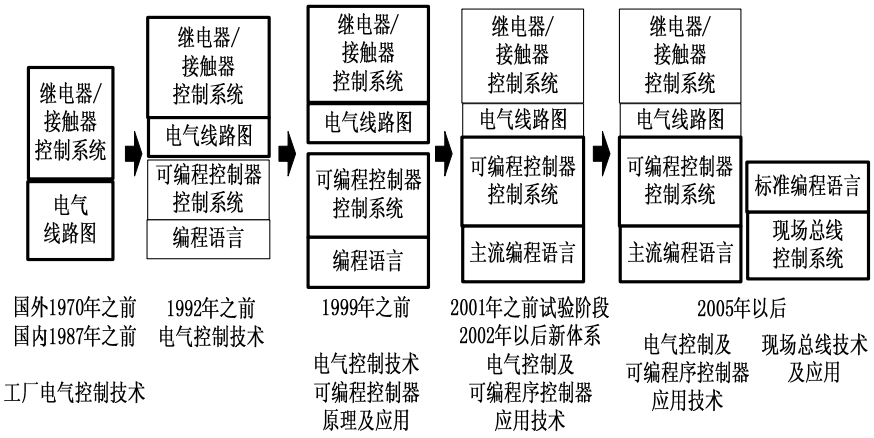

图 1 “电气控制技术”课程的历史沿革
Fig 1 The curriculum changes of “Electrical Control Technology” course in Chinese university

1987 年以前，“电气控制技术”只讲解继电器/接触器控制系统，课程名称一般用“工厂电气控制技术”；之后的几年，可编程序控制器（Programmable Logic Controller, PLC）在国内开始使用，这时期 PLC 主要是用于取代继电器逻辑系统，实现逻辑顺序控制，该课程的内容以继电器/接触器控制系统为主，适当增加了 PLC 的基础知识，编程语言非常简单；1992 年以后，该课程中传统控制技术的内容和 PLC 控制系统的内容基本相当，在大部分学校开设两门课：“电气控制技术”和“PLC 控制系统及应用”；随着 PLC 的快速发展，其过程控制功能和网络通信能力大大增强，2001 年以后，两门课程又合并为“电气控制及 PLC 应用技术”，其中简要讲解继电器/接触器系统的基础知识， PLC 控制技术为主要内容，编程系统使用主流 PLC 编程语言；现场总线技术的发展和成熟，要求对电气控制技术课程体系进行改革，增加新的课程，使用国际标准工业控制编程语言，2005 年以后，该课程体系中的主要课程是“电气控制及 PLC 应用技术”和“现场总线技术及应用”。

现场总线技术对“测控技术与仪器”和“过程控制系统”等课程也产生了较大影响，从早期的“传感器技术”，“DCS 控制系统”发展到“智能传感器技术”、“PLC 控制系统”，再到总线时代的“总线

型传感器技术”，“FCS 控制系统”等，在其授课内容中也必须增添“现场总线技术”的知识。

2.2 新课程设置

1) 国内外现场总线教学现状

虽然基于现场总线的技术及产品早已问世，但总线技术在国内的应用是在2000年以后才逐步开展起来的。国外高校早在2000年前就为电气类学生开设现场总线技术课程，该类高校约占到工科高校的50%左右。而国内目前的现场总线教学工作起步较晚，上世纪90年代后期，清华大学首先为研究生开设了总线课程，稍后浙江大学为本科生也开设了该课程，目前国内开设总线课程的学校约占工科院校的30%左右，但其中大多数仍停留在泛泛的简单介绍和讲授阶段，国内高校还需要加紧专业实验室及教师队伍的建设。

2) 课程设置

在技术进步的要求下，我们认为对电类专业而言，下列课程是非常重要的：

(1)现场总线技术及应用（或工业控制网络技术）：讲述现场总线的工作机制，数据交换的方法，通信报文，系统组态方法及应用案例分析等[3]。

(2)OPC技术及应用：学习软件接口设计技术，进行应用类软件编写，通过OLE技术实现不同软件及平台间数据交换等。

(3)标准编程语言IEC61131-3：它是工业控制领域的标准编程语言，课程主要讲解公共元素、标准软件模型，以及基于开放式标准编程语言的程序设计。

(4)中高级PLC技术及应用：讲解大规模PLC系统配置方式，讲解硬件组态方式、程序运行机制，学习程序块、系统功能块的使用和设计，培养学生复杂程序的编写方法及技巧。

3) 对实验室建设的要求

针对目前在高等院校工程教学中存在的重“学”轻“术”的现象[4]，在信息化和工业化融合相关课程体系中，加强专业实验室建设，增加课程实践教学时间是最重要的。从底层传感器/执行器级的总线，到车间控制级的总线，再到上层的数据处理和管理层的网络，现场总线技术包括的内容很多，必须建设一个信息化和工业化结合的综合性实验室，该实验室不仅能进行各层次工业通信网络的独立实验，也可以进行综合性的工业网络实验，而且也能进行和工业信息化有关的新技术，比如OPC、IEC61131-3编程方面的实验。

国内高校的实验室建设越来越趋于统一化和标准化，但是对于现场总线技术及应用的课程而言，统一的实验平台架构不能对实践教学起到很好的辅助作用。总线类型不同，实验平台也有较大的差别，同时总线技术的安装技术训练也是总线技术的一大特点，所以总线类课程的实验室建设需要各高校根据自身情况，合理设置实践教学内容，配置相应的实验教学平台。

3. 对科研的影响

现场总线技术极大拓展了教师的研究领域及其科研成果应用和转化的空间。

1) 研究课题

现场总线技术是自动化领域的热门技术，同时也是国家产业政策鼓励发展的领域。其数据交换性能的研究、总线网络与传统仪表数据通信技术的研究、总线系统安全性及故障诊断系统的研究、从站设备的开发等都是很好的课题。

(1) PROFIBUS现场总线通信可靠性的研究：对通信报文数据，报文波形绘制，主站从站电平信号捕捉，从站丢失诊断机制，总线循环时间的确定等进行深入研究和分析。

(2) 总线系统安全性能分析研究：在危险性场合，需要高性能安全型的系统和设备，该课题主要研

究基于现场总线系统的本质安全技术及应用。

(3) 总线系统在线诊断技术研究：研究总线的诊断报文及主站的状态信息，借助外部诊断工具或者诊断功能块对报文进行解析，使用HMI动态显示总线系统运行状态。

(4) 具有总线接口从站设备开发：深入研究总线的通信机理及数据交换方式，开发具有特定用途的从站设备。

(5) 功能安全技术：为避免重大事故的发生，将可能发生的危险或损失降到最低，按照各个行业的标准及安全性要求进行现场总线技术功能安全技术研究，从开始电气控制的设计到控制程序的编写，整个控制系统研发的过程中都嵌入功能安全技术的意识。

2) 应用技术领域

现场总线应用技术为高校在高新技术科技成果的转化上增加了新的亮点，和现场总线技术相关的科研成果会越来越多的应用到各个行业中。

(1) PROFIBUS总线实验平台：针对目前高校或者实验院所对总线实验平台的不同需求，设计研发具有多个实验项目的总线实验平台，实验平台应具有灵活的配置方式、良好的技术及接口延展性、丰富的动手操作模式。

(2) 多网络数据集成技术[5]：将已有的各种通信方式采用总线桥的方式融合入总线系统，设计开发总线间的数据交换方式，从而实现多网络数据交换，最终将控制系统的所有网络进行数据集成。

(3) 基于总线技术的数据集成和处理系统：充分体现总线技术的信息集中交互方式的优点，配合简洁的总线网络，通过通信接口访问底层设备，实现大规模的生产过程信息集中监控和处理。

(4) OPC技术应用[5]：采用标准接口技术，实现总线数据在以太网通信方式及不同软件之间数据通信通道的建立，实现各种应用软件之间或软件与底层设备之间的数据通信，从而实现不同网络、不同平台之间数据的共享。

4. 应对措施及实践效果分析

针对现场总线技术对工科院校相关专业教学和科研所带来的影响，在多个方面都进行了一些改革和实践，并取得了很好的效果。

1) 课程体系改革和教材建设工作[6]

从 2000 年开始，把“电气控制技术”和“PLC 控制系统及应用”合并为一门课程，有关低压电器、继电器/接触器系统的基础知识为必讲内容，但学时只占 12~14 学时，重点内容是 PLC 技术。学习对象选取主流的 SIEMENS 公司的 PLC，兼顾到了后续技术发展的知识更新要求。从 2005 年开始，对课程体系进行了较大改革，对高年级本科生和研究生开设“现场总线技术及应用”课程，本科生偏重应用，研究生偏重报文分析、产品开发和系统设计。除此之外，开设了以应用为主的“中高级 PLC 技术及应用”，以及符合工业控制标准编程语言发展要求的“IEC61131-3 编程语言及应用”选修课。为了使学生能融会贯通地掌握传统电气控制系统、PLC 控制系统、国际工控标准编程语言，以及现场总线技术，我们总结绘制了相关知识点的关系图，它可以帮助学生非常容易地理清了学习思路。课程体系改革为培养信息化工业化融合时代高水平电类专业人才提供了保证，如图 2 所示。

好的配套教材是保证新开设课程质量的基础。目前这方面质量上乘的书还不多见，在这里作者推荐两本书，一本是《工业数据通信与控制网络》（阳宪惠编著，清华大学出版社 2003 出版 ），这本书是第一本讲解现场总线技术的书，较详细地介绍了现场总线的基本原理和多种现场总线技术。作者编著的《现场总线技术及应用教程》（机械工业出版社 2007 年出版）也是一本值得使用的教材[1]，现在已被 50 多所大学选用。该书主要详细讲解了工业自动化领域的主流现场总线 PROFIBUS 的原理及应用。教材建设必须

注意选题的正确和准确，要把握信息化和工业化融合所产生的技术点，以及对知识的要求。另外教材内容必须跟上技术的发展速度，不然应用性知识的时效性就得不到保证，这就要求不断对一些内容进行必要的更新和修改。在新版的教材中，准备补充主流工业以太网 PROFINET 技术的内容。

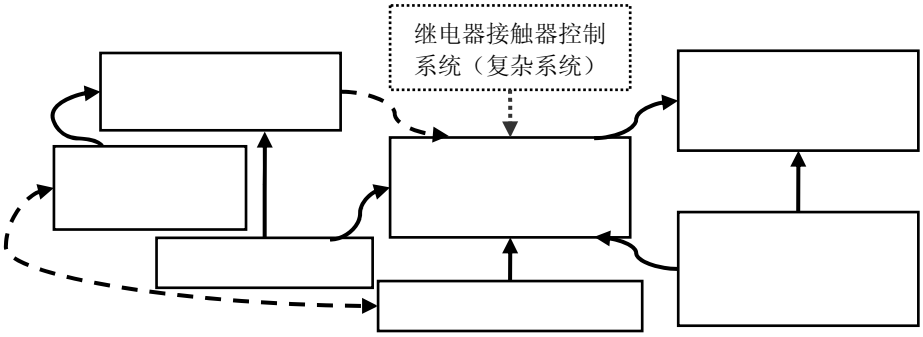

图 2　传统电气/PLC /现场总线控制系统知识点关系图
Fig2　The knowledge key point relationships chart between traditional electrical, PLC and Fieldbus Control SYSTEM

2)专业实验室建设

2006年底，依托于河南省信息化电器重点实验室，创建了“工业控制网络技术实验室”，该实验室使用具有代表性的总线技术，基于工业以太网、PRFIBUS、AS-i三层网络架构设计，涵盖了工业通信网络的高层和底层。拥有自主知识产权的实验平台可完成50余种相关实验。第一个中国PROFIBUS用户组织认证的“中国PROFIBUS/PROFINET技术培训中心”和第一个PLCopen国际组织认证的“中国IEC61131-3培训中心”均设在该实验室。实验室除完成研究生和本科生的实验教学外，还可用于科研开发，在培训工作中，也发挥了重要作用。工业控制网络技术实验室与PROFIBUS工程师资质培训实景分别如图3图4所示。

图 3工业控制网络技术实验室
Fig3 The Lab of Industrial Control Network Technology

图 4 PROFIBUS技术工程师资质培训
Fig4 The Certificate Training Course of PROFIBUS Technology Engineer

3) 以实际工程项目和课题为抓手

与企业联系不够紧密是过去在培养应用型工科人才时的通病，现场总线及其相关技术都是应用性很强的技术，所以和实际工程项目和科研课题相结合是培养创新型人才的重要捷径[7]。实际工程项目和课题的实施，一方面能使任课教师的专业素养和水平大大提高，同时授课内容可以生动活泼，有血有肉；另

一方面也可以提供不少机会，使研究生、本科生的实践动手能力得以极大提高。我们团队保持着年均200万元左右的横向科研经费，这些项目和课题均来自于企业，其中现场总线技术和PLC控制系统方面的项目占90%左右。工程项目的开发和实施中，学生自始至终参与其系统配置、组态、软硬件系统设计、现场调试等各个环节的工作。我们现在的优势项目集中在“基于现场总线技术的纺织生产过程信息集成及处理系统”和“基于PROFIBUS的FCS实时故障诊断和状态报告系统”。

5．结论

现场总线技术对高校相关专业的教学和科研提出了新的要求，要跟上技术进步的步伐，适应新形式对高水平专业人才培养的要求，就必须在课程体系改革和应用技术更新方面与时俱进。本文提出了一些应对措施，并对其进行了成功实践。在课程体系改革方面，加大相关工业通信网络技术方面的课程比重，并增加相关选修课程，使知识点做到上下传承，融会贯通；针对具体应用，选取主流现场总线技术建设高水平综合性的实验室和技术中心，并做到功能性和实用性的统一[8]，满足不同层次的实验、培训和科研要求；实际工程项目和课题在培养创新型人才方面起着不可替代的作用，把实际工程项目的实施和人才培养相结合，可以培养与造就出真正高质量、多层次的工程技术人员。做好以上几个方面的工作，就完全可以应对现场总线技术发展给高校教学和科研工作所带来的影响和要求。

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A TEACHING IDEA ON NEGATIVE FEEDBACK AMPLIFIER

LU LI-ZHONG

Institute of Information Engineering ,Information Engineering University,

Zhengzhou china 450002

lhk21@263.net

Abstract: Combined with comprehension and teaching practice,the paper proposes a proper teaching idea on negative feedback amplifier ,which could be offered to the teacher engaged in the course of electronic circuit to refer to.

Key word: negative feedback, negativefeedback amplifier, teaching idea

关于负反馈放大器的一种教学思路

陆利忠

郑州信息工程大学 信息工程学院，河南 郑州 中国 450002

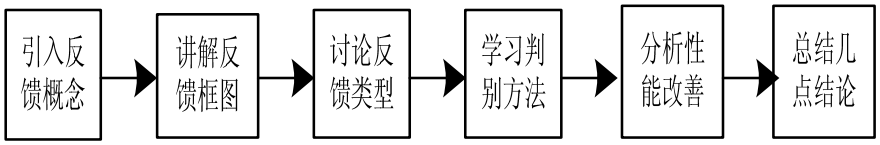
摘要：本文结合作者对负反馈放大器内容的理解和教学实践提出了一种自己的教学思路, 可为从事电子线路课程教学的教师提供教学参考。

关键词：负反馈; 负反馈放大器; 教学思路

1. 引言

负反馈技术是放大器中常用的一种技术，用它可以改善放大器的许多性能指标。如今几乎不可能抛开反馈理论来讨论放大器的设计。

负反馈放大器历来是电子线路课程中的一个重点和难点内容，但是这部分内容新概念多、具体电路复杂，学生往往不会从电路中找到反馈元件和判别反馈类型，故初学者学习这部分内容感到吃力。本文根据作者从事该内容教学多年，结合自己的体会，提出一种负反馈放大器的教学思路。总体教学思路如下。



2. 从实例引入反馈概念

例 1：观众在剧场观看到精彩的演出时，会报以热烈的掌声，这种掌声会进一步激发演员的演出热情，并使演出效果更好。这里的掌声就是观众对演员的演出节目的一种反馈。

例 2：用学生已有的放大器直流工作点的稳定引入反馈，见图 1 所示。在讲解放大器直流工作点稳定的原理后引入反馈概念。

通过上两例引导后，逐步深入。引入反馈放大器的基本概念，给出反馈放大器的方框图和反馈的定义，即：反馈就是把放大器的输出信号通过一定的电路返回到输入端。讲解这个定义要结合方框图，明确取样、比较、反馈网络和基本放大器几个环节。还要讲清交流反馈、直流反馈、内部反馈、外部反馈、负反馈和正反馈等概念。强调这里讨论的是外部交流负反馈，目的是用于放大器改善性能。

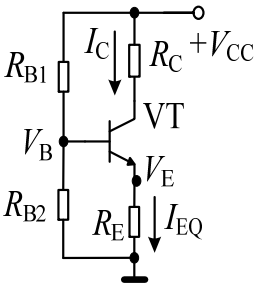


图 1 晶体管放大器
Fig.1 Transistor amplifier

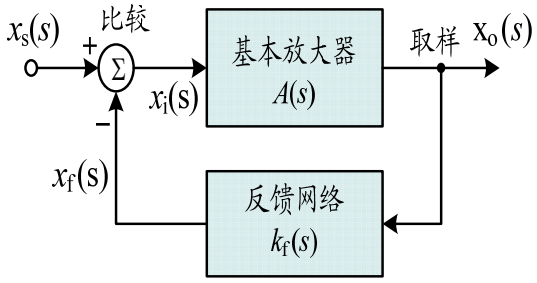


图 2 负反馈放大器的方框图
Fig.2 Negative feedback amplifier block diagram

3. 讨论反馈放大器的基本关系

从图 2 可推导出如下基本关系。开环增益为：

$$A(s)=x_o(s)/x_i(s) \tag{1}$$

反馈系数为：

$$k_f(s)=x_f(s)/x_o(s) \tag{2}$$

净输入信号为：

$$x_i(s)=x_s(s)-x_f(s) \tag{3}$$

闭环增益为：

$$A_f(s)=\frac{x_o(s)}{x_s(s)}=\frac{A(s)}{1+k_f(s)A(s)}=\frac{A(s)}{F(s)} \tag{4}$$

环路增益为：

$$T(s)=k_f(s)A(s)=x_f(s)/x_i(s) \tag{5}$$

反馈深度为：

$$F(s)=1+k_f(s)A(s) \tag{6}$$

根据环路增益表达式，对几种可能出现的情况进行讨论，指出正反馈、负反馈、深度负反馈等基本概念，并结合输入输出信号为电压或电流两种情况，确定反馈系数和开环增益、闭环增益的量纲，进而指出共有四种反馈放大器类型。如图 3 所示。

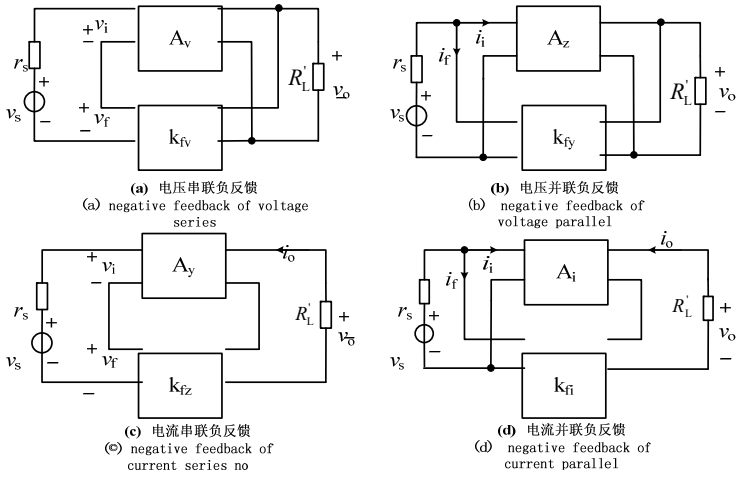


图 3 四种反馈放大器类型

Fig.3 four types of negative feedback amplifier

4. 反馈放大器的类型判别

用短路法判别取样信号，用开路法判别比较方式，用瞬时极性法判别反馈性质。

由式(2)可知，反馈信号正比于取样信号，据此可以判断取样信号。可假设将输出端短路，若反馈信号消失则为电压取样，否则为电流取样，此法可称为短路法。根据反馈放大器方框图可知，若将信号源(含内阻)开路，若反馈信号不能加到基本放大器输入端则为串联比较(比电压)，否则为并联比较(比电流)，此法可称为开路法。对于反馈性质的判断则应依据具体电路，观察反馈信号使净输入信号增大还是减小，如果是增大则为正反馈，否则为负反馈。

介绍上述方法后可举具体电路实例，对于判断反馈类型用的电路可以稍微复杂一些，对于计算用的电路可以简单一些，目的是作一个比较，说明负反馈分析方法的运用。

例如，设图 (4)中 $R_C = R_L = 5\text{k}\Omega$，$R_E = 500\Omega$，$r_s = r_\pi = 1\text{k}\Omega$，$\beta = 50$。判断放大器的反馈类型，并求闭环电压增益 A_{vsf} 的值。

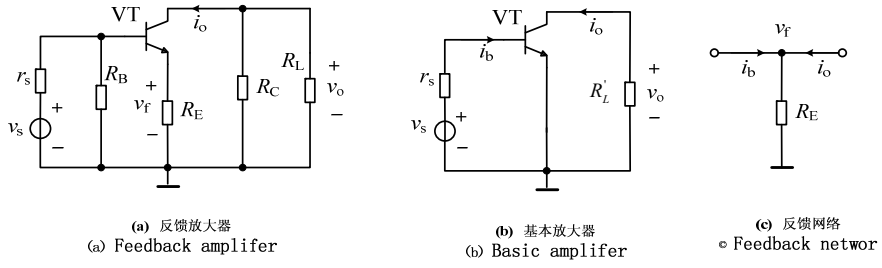


图 4 举例用图

Fig. 4 example figure

这是一个共发射极放大电路，反馈元件为 R_E。由该电路可见，若把交流负载短路时 v_o=0，但 i_o不为零，故反馈电压 v_f不会消失，因此取样信号是电流。若把信号源(含偏置元件)断开时，v_f不能加到晶体管输入端，因此为串联比较。当输入端信号增加时，v_f也增加(跟随关系)，则加到晶体管的信号电压 v_{be}(净输入信号)减小，因此为负反馈。所以，该放大器是一个电流串联负反馈放大器。

作为一种近似计算,若 $R_B >> r_s$ 且在不考虑反馈网络对基本放大器的负载作用时可将图4(a)的反馈放大器拆分为图 2.5.3(b)所示的基本放大器和图 2.5.3(c)所示的反馈网络。因为是电流串联负反馈放大器,取样信号为电流 i_o,比较信号为电压,所以反馈系数应为 k_{fz},表示为:

$$k_{fz} = \frac{v_f}{i_o} = \frac{(i_o + i_b)R_E}{i_o} \approx R_E$$

基本放大器源互导增益为:

$$A_{ys} = \frac{i_o}{v_s} = \frac{\beta i_b}{i_b(r_\pi + r_s)} = \frac{\beta}{r_\pi + r_s}$$

则反馈深度为:

$$F = 1 + A_{ys}k_{fz} = 1 + \frac{\beta R_E}{r_s + r_\pi} = \frac{r_s + r_\pi + \beta R_E}{r_s + r_\pi}$$

闭环互导增益为:

$$A_{ysf} = \frac{A_{ys}}{F} = \frac{\beta}{r_s + r_\pi + \beta R_E}$$

因此,闭环电压增益为:

$$A_{vsf} = \frac{v_o}{v_s} = -\frac{i_o R_L^{'}}{v_s} = -A_{ysf}R_L^{'} = -\frac{\beta R_L^{'}}{r_s + r_\pi + \beta R_E}$$

将例题数据代入上式得:

$$A_{vsf} = -\frac{\beta R_L^{'}}{r_s + r_\pi + \beta R_E} = -\frac{50 \times 2.5}{1 + 1 + 50 \times 0.5} \approx -4.6$$

当电路满足深度负反馈条件时,可直接得到闭环互导增益为:

$$A_{ysf} = \frac{1}{k_{fz}} = \frac{1}{R_E}$$

则闭环电压增益为:

$$A_{vsf} = \frac{v_o}{v_s} = -\frac{i_o R_L^{'}}{v_s} = -A_{ysf}R_L^{'} = -\frac{R_L^{'}}{R_E} = -\frac{2.5}{0.5} = -5$$

可见两种计算结果差别不大。事实上本例题已经满足深度负反馈条件了。

5. 负反馈对放大器性能的影响

在上述讨论的基础上，接着就可以讨论负反馈对放大器性能的影响，仅讨论主要指标即可。

1) 降低增益灵敏度

则把放大器增益受外界因素的变化而变化的灵敏程度称为增益灵敏度。定义为：

$$S_{\mathrm{k}}^{\mathrm{A}}=\frac{\partial \ln A(k)}{\partial \ln k} \tag{7}$$

式中:A(k)为放大器的增益函数,k为受外界因素变化的参数,如负载电阻R_{L}、信号源内阻r_{S}或晶体管的β、r_{e}等。以增量代替微分,将上式写成增量表示的形式为：

$$S_{\mathrm{k}}^{\mathrm{A}}=\frac{\Delta A(k)/A(k)}{\Delta k/k} \tag{8}$$

所以,增益灵敏度表示增益 A 的相对变化量与引起增益变化的参数 k 的相对变化量之比。
对于反馈放大器,按式(7)定义,闭环增益 A_{f}(k)对参数 k 的灵敏度为：

$$S_{k}^{A_{\mathrm{f}}}=\frac{\partial \ln A_{\mathrm{f}}(k)}{\partial \ln k}=\frac{\partial \ln A_{\mathrm{f}}(k)}{\partial \ln A(k)}\cdot\frac{\partial \ln A(k)}{\partial \ln k}=S_{A}^{A_{\mathrm{f}}}S_{\mathrm{k}}^{\mathrm{A}}$$

根据式(4)可得：

$$S_{A}^{A_{\mathrm{f}}}=\frac{\partial \ln A_{\mathrm{f}}}{\partial \ln A}=\frac{1}{1+Ak_{\mathrm{f}}}=\frac{1}{F} \tag{9}$$

所以：

$$S_{k}^{A_{\mathrm{f}}}=S_{\mathrm{k}}^{\mathrm{A}}/F \tag{10}$$

即反馈放大器的增益 A_{f} 对参数 k 的灵敏度是基本放大器增益 A 对参数 k 的灵敏度的 F 分之一。
2) 扩展通频带

若单极点基本放大器的增益为：

$$A(\mathrm{j}\omega)=\frac{A_{\mathrm{o}}}{1+\mathrm{j}\omega/\omega_{\mathrm{p}}} \tag{11}$$

式中：A_{o}为低频增益。组成反馈放大器后,反馈系数为 k_{f},则闭环增益为：

$$A_{\mathrm{f}}(\mathrm{j}\omega)=\frac{A(\mathrm{j}\omega)}{1+k_{\mathrm{f}}A(\mathrm{j}\omega)}=\frac{A_o/(1+\mathrm{j}\omega/\omega_{\mathrm{p}})}{1+k_{\mathrm{f}}A_o/(1+\mathrm{j}\omega/\omega_{\mathrm{p}})}=\frac{A_o/F_o}{1+\mathrm{j}\omega/F_o\omega_{\mathrm{p}}} \tag{12}$$

式中：$F_{\mathrm{o}}=1+A_{\mathrm{o}}k_{\mathrm{f}}$为低频时的反馈深度，令：$A_{\mathrm{of}}=A_o/F_o$

为低频时的闭环增益。令：$\omega_{\mathrm{pf}}=F_o\omega_{\mathrm{p}}$

为反馈放大器的极点频率。于是可将式(2.5.24)表示为：

$$A_{\mathrm{f}}(\mathrm{j}\omega)=\frac{A_o/F_o}{1+\mathrm{j}\omega/F_o\omega_{\mathrm{p}}}=\frac{A_{\mathrm{of}}}{1+\mathrm{j}\omega/\omega_{\mathrm{pf}}} \tag{13}$$

所以,闭环带宽 ω_{pf} 是开环带宽 ω_{p} 的 F_{o} 倍。这也就意味着当基本放大器带宽不够宽而存在频率失真时可

以用负反馈来展宽通频带,以减少放大器的频率失真。

3）对输入电阻和输出电阻的影响

这里应指出比较方式影响放大器的输入电阻，取样方式影响放大器的输出电阻。按串联比较和并联比较分析负反馈对输入电阻的影响，如图 5 所示，对于串联比较和并联比较，输入电阻分别为:

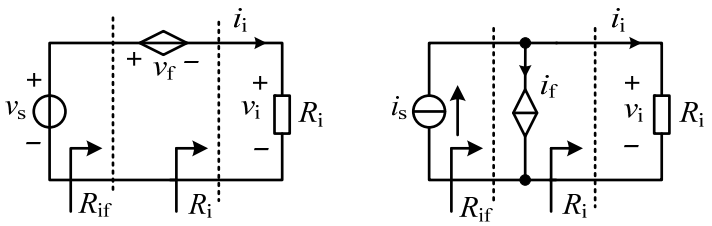


图 5 负反馈放大器输入电阻分析

Fig.5 Negative feedback amplifier input resistance analysis

$$R_{if}=R_i+\frac{k_f A v_i}{i_i}=R_i+k_f A R_i=\left(1+k_f A\right)R_i=F\cdot R_i \tag{14}$$

$$R_{if}=\frac{v_i}{i_i+k_f A i_i}=\frac{R_i}{1+k_f A}=\frac{R_i}{F} \tag{15}$$

分析放大器的输出电阻，如图 6 所示，对于电压取样和电流取样，输出电阻分别为：

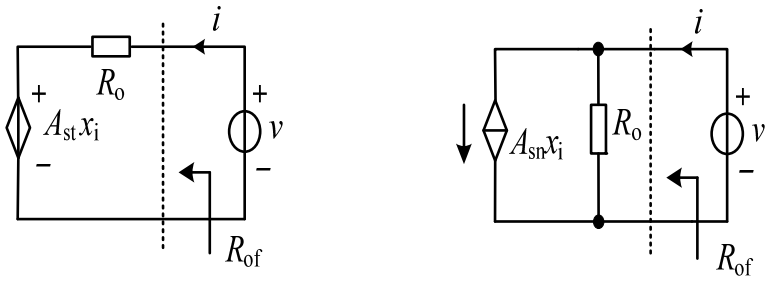


图 6 负反馈放大器输出电阻分析

Fig.6 Negative feedback amplifier output resistance analysis

$$R_{of}=\frac{v}{i}=\frac{R_o}{1+k_f A_{st}}=\frac{R_o}{F_{st}} \tag{16}$$

$$R_{of}=\frac{v}{i}=\left(1+A_{sn}k_f\right)R_o=F_{sn}R_o \tag{17}$$

这里应重点强调 F_{sn} 和 F_{st} 的区别。

4）对源增益的影响 这里有两种情况:

（1）反馈放大器的源增益是基本放大器源增益的 1/F 倍。即

电压串联负反馈 $$A_{\mathrm{vsf}}=\frac{A_{\mathrm{vs}}}{1+k_{\mathrm{fv}}A_{\mathrm{vs}}}=\frac{A_{\mathrm{vs}}}{F_{\mathrm{vs}}},\quad F_{\mathrm{vs}}=1+k_{\mathrm{fv}}A_{\mathrm{vs}}$$ (18)

电压并联负反馈 $$A_{\mathrm{zsf}}=\frac{A_{\mathrm{zs}}}{1+k_{\mathrm{fy}}A_{\mathrm{zs}}}=\frac{A_{\mathrm{vs}}}{F_{\mathrm{zs}}},\quad F_{\mathrm{zs}}=1+k_{\mathrm{fy}}A_{\mathrm{zs}}$$ (19)

电流串联负反馈 $$A_{\mathrm{ysf}}=\frac{A_{\mathrm{ys}}}{1+k_{\mathrm{fz}}A_{\mathrm{ys}}}=\frac{A_{\mathrm{ys}}}{F_{\mathrm{ys}}},\quad F_{\mathrm{ys}}=1+k_{\mathrm{fz}}A_{\mathrm{ys}}$$ (20)

电流并联负反馈 $$A_{\mathrm{isf}}=\frac{A_{\mathrm{is}}}{1+k_{\mathrm{fi}}A_{\mathrm{is}}}=\frac{A_{\mathrm{is}}}{F_{\mathrm{is}}},\quad F_{\mathrm{is}}=1+k_{\mathrm{fi}}A_{\mathrm{is}}$$ (21)

（2）当反馈放大器的类型确定后，四种源增益均减小相同的倍数，即同时成立下面的关系：

$$\text{（1）}\ A_{\mathrm{vsf}}=\frac{A_{\mathrm{vs}}}{F_{\mathrm{s}}};\quad \text{(2)}\ A_{\mathrm{isf}}=\frac{A_{\mathrm{is}}}{F_{\mathrm{s}}}\quad \text{(3)}\ A_{\mathrm{zsf}}=\frac{A_{\mathrm{zs}}}{F_{s}}\quad \text{(4)}\ A_{\mathrm{ysf}}=\frac{A_{\mathrm{ys}}}{F_{\mathrm{s}}}$$ (22)

对以上关系可以例举一二加以证明。

6．结论

教学内容是为培养人才的需要而设计的，教学方法和思路也因教师的教学特点和对内容的理解而没有固定的模式。但笔者认为，对于负反馈放大器的教学应以反馈的基本概念和深度反馈分析为重点。以上仅是作者对反馈放大器教学内容的理解，仅供同行参考。

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THE APOCALYPSE OF THE INNOVATION IN ELECTRIC-INFORMATION COURSES OF FAMOUS INSIDE AND OUTSIDE UNIVERSITIES

KU XI-SHU, DING WEN-XIA, TU RUI-BIN,LI GUI-LIN,CHEN HONG

School of Electronic Science and Engineering,NUDT, Changsha 410073,China

kuxishu@126.com

Abstract：With the rapid development of electronic technology and information technology as well as the change of professional education mode, cultivating high-quality innovative talents becomes an urgent demand for the vigorous development of electronic information industry, which puts forward higher requirements for higher education in China. It's urgent for us to select teaching contents, introduce new technology and methods, restructure the knowledge structure and build reasonable system of series curriculum. This paper thoroughly analyzes and compares the curriculum system of circuit courses in some inner universities. The innovation trends of circuit courses in these famous institutes are concluded. Furthermore, the main problems existing in the reform of circuit courses in these universities are discussed also.

Key words：Electronic information; education mode; curriculum system; innovation trend

国内外知名高校电子信息类课程体系改革之启示

库锡树　丁文霞　涂瑞斌　李贵林　陈虹

国防科技大学 电子科学与工程学院，湖南 长沙 中国 410073

摘 要：当前，随着电子技术和信息技术的飞速发展及专业教育模式的转变，电子信息产业的蓬勃发展亟需高素质创新人才，这对我国高等教育提出了更高的要求，我们迫切需要在教学过程中精选教学内容，引进新技术、新方法，重组知识结构，架构合理的系列课程体系。本文即从课程体系架构方面将多所国内外知名高校的电路系列课程体系进行了深入分析与比较，并对目前国内知名院校电路系列课程体系的改革趋势进行了总结与探讨。

关键词：电子信息；教育模式；课程体系；改革趋势

1. 引言

当前，随着电子技术和信息技术的飞速发展及专业教育模式的转变，电子信息产业的蓬勃发展亟需高素质创新人才，这对世界各国高等教育提出了更高的要求。为结合当前电子技术和信息技术的发展需要，同时为更好的培养学生采用新知识、新技术、新方法和新手段分析问题、解决问题的能力，我们迫切需要在教学过程中精选教学内容，引进新技术、新方法，重组知识结构，架构合理的系列课程体系，完善课程设置，同时经常性地优化人才培养方案。目前，国内外许多知名高校，如英国剑桥大学、牛津大学，美国麻省理工（MIT）大学、哈佛大学、西点军校，美国空军军官学校、英国皇家军事科学院、韩国海军军官学校、澳大利亚墨尔本大学等国外名校及国内清华大学、北京大学、中国科技大学、浙江大学、上海交通大学、北京理工大学、东南大学、成都电子科技大学、西安电子科技大学等学校均已对电

子信息类课程体系的重新整合和合理架构展开了深入研究，提出了许多有建设性、有参考价值的改革思路和意见。

本文即基于此背景，从课程体系架构方面对 MIT、斯坦福、清华大学、国防科学技术大学等多所国内外知名高校现行对应的电路系列课程体系进行深入分析与比较，并对目前国内外电路系列课程体系的改革趋势进行总结分析与问题探讨。

2. 国内外知名院校电路系列课程体系架构对比

近期，斯坦福大学电气工程系和麻省理工学院的电气工程和计算机科学系对本科生课程设置进行了改革。两所大学改革后的共同点是强调实践应用、加强核心课程的实验教学、突出系统概念而不是器件、强化软硬件的联系。

1）斯坦福大学电气工程系核心基础课课程体系分析

斯坦福大学电气工程系原设置了六个领域的课程，分别是计算机硬件、软件、控制、电子、场与波和信号处理与通信。在新的设置中，可归为四大领域：数字系统、信号系统与控制、电子学和场与波。场与波领域没有安排核心课程，而是直接设置高年级深度课程。其他三大领域核心课程安排如图 1 所示.

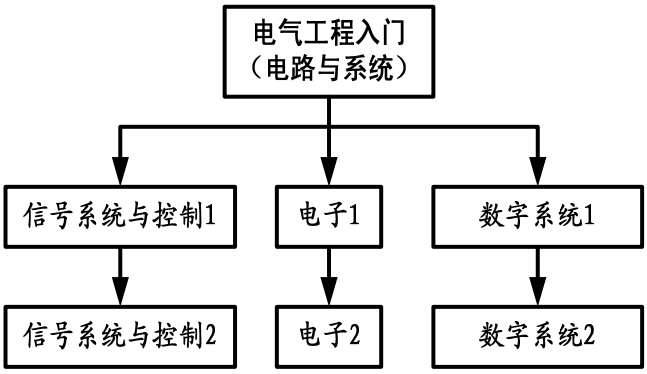

图 1　斯坦福大学电气工程学院核心基础课
Fig.1 The core Basic Courses System of the Electrical Engineering school for Stanford University

三个领域的核心课程是并行设置的,下面分别介绍：

（1） 信号系统与控制：课程学习目的是引入设计和分析电子信号与系统所用的数学模型和工具。课程学习顺序建议信号系统与控制 1 为连续时间信号与系统，信号系统与控制 2 为离散时间信号与系统。通过通信、信号处理和控制论的应用实例来讲述基本概念及相关技术。实验部分采用 Matlab 实习及项目来阐明概念和技术应用。

（2） 电子学：设置目的为学习电子线路建模和分析。课程电子学 1 主要是介绍几种电子线路模型，而不是集中于复杂的半导体器件，这有助于学生用相对简单模型来分解评估复杂系统。电子学 2 集中在模拟电路的设计方面，借助于电子学 1 中所了解的基本概念模型，以系统的观点来整合这些概念模型，并分析该系统设计。

（3） 数字系统：教学目的是介绍数字硬/软系统的设计和构成。实验课以计算机系统为例贯穿始终。数字系统 1 讲授数字电路逻辑与基本系统设计，其实验与理论讲授同步进行，包括从晶体管设计门电路到 ROM；进一步过渡到 Verilog 和 FPGA 的使用；该课程的最终实验结果是基于微序列器和外部存储器设计一个整数运算器。

由图 1 可知，相对于该系统以前的课程设置，斯坦福大学电气工程新设置减少了课程数量，简化了体系结构。作为电气工程专业基础入门课程，电路与系统得到了保留，但要求进一步修改此课程以利于解决两个关键问题：满足电气信息类所有专业要求的入门课程而不仅仅是电子工程专业的；课堂教学面向应用，以增加学生的学习兴趣，如该课程建议其课堂教学基于无线遥控汽车来进行。

2）麻省理工（MIT）电气&计算机科学系基础课课程体系分析

麻省理工（MIT）的电气&计算机科学系能够授予三个专业的学士学位，分别为电气科学与工程、计算机科学与工程和电气工程与计算机工程。在以前的课程设置中，该系核心课程为计算机程序结构、电路、信号与系统，以及计算机架构。以电气科学与工程专业为例，其新设置的核心基础课程由两门入门课、三门基础课以及三门专业基础课组成，结构如图 2 所示。

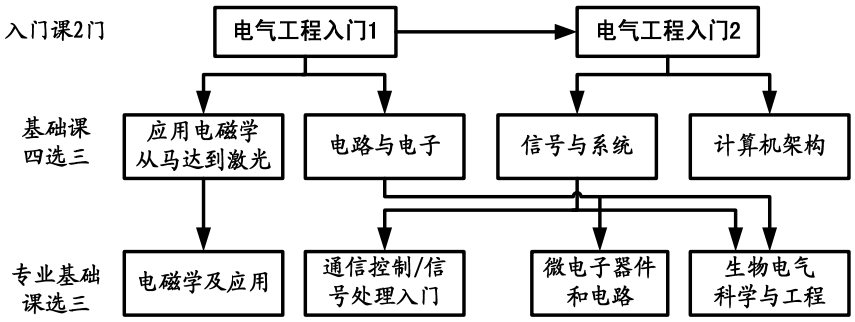

图 2　麻省理工电气科学与工程专业基础课

Fig.2 The special Basic Courses System of the Department of Electrical Science & Engineering for MIT University

传统的入门课程通常是先介绍模型概念，再通过实验课验证，而麻省理工学院颠覆了这一传统教法。改革后的两门入门课完全是基于实验课的，其目的是通过学生直接参与实验来归纳模型，加强概念认知，鼓励探索。该教学方法源于最朴实的理论形成过程，如图 3 所示。

图 3　麻省理工电气科学与工程专业入门课教学过程

Fig.3 The Teaching process of the Electrical Science and Engineering speciality for MIT University

这两门入门课面向该系 3 个专业所有的学生，其中入门 2 要求以入门 1 为预备课。与斯坦福的无线遥控汽车类似，入门 1 中实验是基于移动机器人。利用机器人平台，学生可以通过计算机软件、线性系统、电路以及人工智能算法等技术来探索或实现自己的想法。

3）国防科技大学电子科学与工程学院课程体系分析(09 方案)

为适应高等教育改革发展趋势，加强素质型军事人才培养，2008 年 10 月起，国防科技大学电子科学与工程学院在原有 2002 电子技术基础系列课程体系结构的基础上，充分吸收国内外重点院校该课程体系

建设的经验，依据该校的实际需要和军队特色，建设了符合该校建设需求的 2009 课程体系，如图 4 所示。

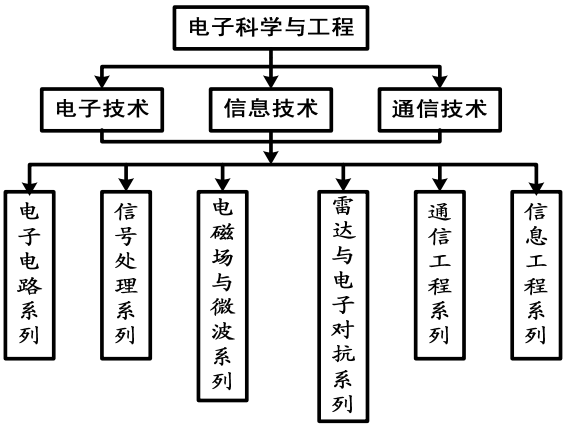

图 4　国防科技大学电子科学与工程学院基础课课程体系
Fig.4 The Courses System of School of Electronic Science and Engineering of National University of Defense Technology

国防科技大学电子科学与工程学院目前能够授予三个专业的学士学位，分别为电子技术、信息技术和通信技术，与此同时，该课程体系融入了较强的军队特色，特设了雷达与电子对抗等专业课程系列。

4）浙江大学信息与电子工程学系课程体系分析

浙江大学信息与电子工程学系主要包括信息与通信工程和电子科学与技术两大学科，其课程体系如图 5 所示。

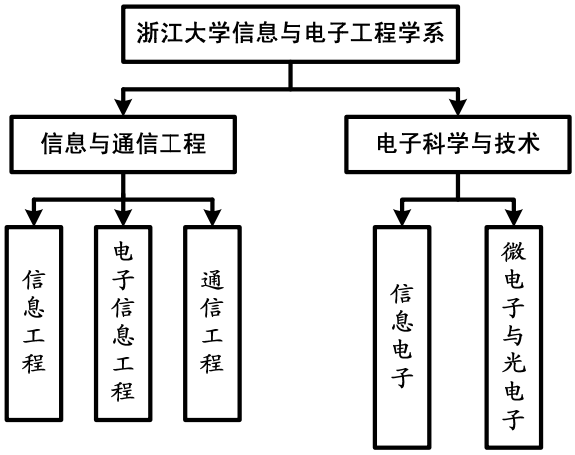

图 5　浙江大学信息与电子工程学系课程体系
Fig.5 The Courses System of Information and Electronic Engineering of Zhejiang University

信息与通信工程专业是将信息工程（信电）、电子信息工程（信电）、通信工程 3 个强势专业实质性交叉融合而创建的新专业，下设信息工程方向、通信工程方向、电子信息工程方向 3 个方向，学生应修读该专业的公共主干课程和 1 个方向的模块课程；电子科学与技术学科则是无线通信、光通信、信息电

子、光电子、微电子这些领域的技术基础，主要培养具备微电子学、信息电子学、光电子学、光纤电子学、集成电路设计和制造、光通信器件与系统、射频与微波技术等宽口径专业知识、以及研究开发与管理能力的复合型高层次创新人才。

3. 国内外知名院校电路系列课程体系改革趋势对比分析

1）国外知名院校课程体系改革呈宽学科、宽专业趋势

由图 2 和图 3 所示的斯坦福大学电气工程系和麻省理工学院（MIT）的电气&计算机科学系课程体系结构图可知，目前国外知名院校电路系列课程体系改革呈现出多学科、多专业融合的趋势，体现为宽学科、宽专业发展。

如 MIT 即将电气工程和计算机科学两大学科合并，一起设课，由学生依据自己感兴趣的方向进行选课，由 MIT 电气&计算机科学学科开放式网络课程的详细资料可知，该课程体系不仅完全融合了电路、信号、微波等常规电路与系统课程体系，还大大突出了集成电路、微电子技术、微电子元件与电路、微电子工艺、电力电气及计算机学科相关课程的设置，这使得该校电气工程与计算机科学方向的学生在大学期间共有近 200 门课程可供选修，知识覆盖面精细而广泛。

2）国内知名院校课程体系改革仍保留较强的学科概念及强调特色

我校电路系列课程体系与国内知名院校（如清华大学、北京大学、中国科技大学、浙江大学、上海交通大学等重点院校）的课程体系基本相同，这些院校大都保留了原有经典的架构，专业方向基本包括电路、信号、微波三大分支，与其它学科融合架构的目前还未普及。相对国外知名院校，国内重点院校更注重于保留延续的学科特色，如我校即保留了既定的军队特色，突显了现代国防观念，且学科与学科之间界限分明，既相互联系，又自成体系，这点与国外著名军校（如西点军校，美国空军军官学校、英国皇家军事科学院、韩国海军军官学校等）比较相似。与此同时，部分学校也已开始课程体系的融合，着手建设宽学科、宽专业的课程体系，如浙江大学，清华大学等均已走在前列。

4. 国内高校电路系列课程体系改革存在的主要问题探讨

1）有限学时与高素质培养的矛盾要求进一步加大课程体系整合的力度

与国外知名院校课程体系改革相比，国内大部分高校电路系列课程体系基本保留了原有经典的架构，专业方向基本包括电路、信号、微波三大分支，与其它学科融合的力度不强，学科与学科之间界限分明。

然而，从斯坦福大学、MIT 等国外知名大学课程体系改革我们可以看出，目前世界高教体系正朝着宽学科、宽专业趋势发展。对本科教育而言，重要的是强调基础，于是，过早的学科及专业划分不利于基础知识的深入理解和知识面的拓宽，同时也不利于解决有限学时与高素质培养的矛盾，因而本科教育中学科与专业融合的趋势日趋明显，因此国内各高校的课程体系整合力度可以考虑是否还应进一步加强。

2）实践能力培养在课程体系中应占有越来越重要的地位

加强实验实践部分是基础课程改革的重要任务。许多国外知名院校的课程改革都考虑了该方面，要求基础课程都配有相关实验课，为激发学生的创新意识，很多实验没有设定最终结果，而是鼓励学生自由发挥和探索。而国内高校在实践教学方面面临的改革形式非常严峻，如当前，由于课外实验时间紧缺、学生没有自主学习时间、课程及军事训练负担过重等因素的影响，我国大部分高校电路基础课程实验基本仍以“验证型”实验为主，目前，仅有小部分学生可以通过参加各种课外活动和竞赛活动来进一步提升自己的动手能力和创新能力，这对提高学生整体学习兴趣，激发他们的创新意识无疑是非常不利的。

3）总体教学运行管理机制改革力度需加大

由以上几方面的探讨我们不难看出，相对国外知名大学的教育情况，国内大部分高校目前在教育理念、教学方法、教学形式和教学效果等方面还存在较大差距。这并不表示我们在这些方面没有想法，止步不前，而是，目前，我国高等院校（尤其是军事类院校）的管理体制在对学生学习时效方面存在一定的矛盾，我们的许多教学思路均基于学生有大块的自主学习时间才能保证其效率，而这正是我们目前面临的最大问题。如何平衡这两方面的关系，制定并完善一套合理的教育教学运行管理机制，这值得我们所有的有识之士去思考、去探索、去实践。

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MARKETING KNOWLEDGE

FENG QIAO-LING,FENG JIAN-QIN

Zhengzhou University of Light Industry, Zhengzhou, 450002, China

Abstracts: We knew that knowledge also needs to sell as merchandise through the graduate forum. And summed up the four-step of marketing knowledge according to the previous teaching experience: professional sale promotion, sale promotion before class, sale promotion during playtime and after school. We achieved good teaching effect by the use of electrical engineering and automation professions, "Electrical Engineering Fundamentals" and other professional courses. Practice has proved that the four-step of marketing knowledge is a good way for students willing to learn, active learning, continue learning.

Key words: marketing knowledge, teaching methods, active learning

推销知识

冯巧玲　冯建勤

郑州轻工业学院, 河南 郑州 中国 450002

摘要:通过毕业生座谈会，使我们了解到，知识和商品一样，也是需要推销的。根据以往教学经验，总结出推销知识的四步曲：专业推销，课前推销，课间推销和课后推销。通过在电气工程及自动化专业《电气工程基础》及其他专业课程中的运用，取得了良好的教学效果。实践证明，推销知识四步曲是让学生愿意学习、主动学习、继续学习的好方法。

关键词:推销知识；教学方法；主动学习

1. 引言

让学生学会更多的知识，报效祖国和社会，是很多教师一生的追求。然而，不是每个老师都能如愿以偿的，其中的原因很多，不会推销知识也是其中之一！

2. 知识也需要推销

我们每年都要开毕业生座谈会，大多数的学生都畅所欲言，我们听到学生对四年的学习和生活的总结，既有对学校和教师的表扬，也有对不满意的地方提出批评，其中几位学生的谈话对我振动较大。

一位学生说："我们去找工作，面试官给出一些专业问题，因上课时不知道它的重要性，没有好好学，答不上来，结果失去了很好的就业机会。"

还有一些学生说："我们学习某某课程，不知学完以后干什么，只是被动的学习，结果成绩就不理想。老师当时怎么不给我们多讲一下它的重要性，我们如果知道了它的重要性，对它产生了兴趣，就会努力学习，即使课堂上学不完，我们以后也会继续学习，知识也是需要推销的。"

知识也需要推销？我们经常看到的是商品的推销和商业大片的推销。试想，如果不了解了商品的用处和好处，就不会去购买；如果商业大片不是很有吸引力，就不会花大价钱去看。天底下最想教会别人知

识的就是老师了。教师向学生传授知识和商人推销自己的商品的愿望是一样的,只有仔细策划和推销，才能让学生主动学习、继续学习和轻松学习[1]。

3. 推销知识的四步曲

根据以往的教学经验，经过认真思考和不断的探索，总结出推销知识的四个步骤：即专业推销、课前推销、课间推销和课后推销。下面逐一分析：

3.1 专业推销

学生上大学报志愿很多是盲目的，有的是老师给报，有的是家长给报。选择的原因一般是下列几个：

1) 是不是好就业；

2) 是不是挣大钱；

3) 是不是能考上；

4) 是不是自己感兴趣的。

而学生对专业本身大多是不了解的。因此，学生进校后，如果不对学生进行详细的专业推销，根据以往的经验，后果是严重的。

例如，大学一年级的学生往往会出现较多考试不及格和考试分数偏低的现象，若与之交流，学生会说：“我不知道学这专业毕业后能干什么!”由此可见，专业推销没有做好，也是影响学生学习的重要原因之一。

注意：我这里说的是“专业推销”，而不是简单的专业介绍。推销和介绍的区别是内容和语气的强弱不一样。推销的特点是实事求是的把产品的用处、好处表现的淋漓尽致。

专业推销内容可以是下面几方面：

(1) 本专业是培养哪方面的人才，可以到哪里就业，是不是社会急需的，是不是很有用的;

(2) 都需要学习哪些课程，只有努力学习，走向社会才可能成为祖国的栋梁，社会的精英，独挡一面的专家等。

3.2 课前推销

每一个专业都有精心设置的几十门课程，每一门课程对人才的培养都有举足轻重的作用，要想让学生学好每门课程，上课第一节必须做好课前推销。

课前推销的具体内容可以是：

1) 为什么要学习该课程；

2) 本门课程在整个课程体系当中的位置；

3) 本门课程要讲授的内容；

4) 本门课程要完成的任务；

5) 该课程对以后的工作和人生有什么用处等[2]。

3.3 课间推销

我们要讲的每节课，都希望学生掌握，并能举一反三，灵活运用。这就需要课间推销艺术。

课间推销的具体内容可以是：

本节课在生产、生活中的具体应用；若不掌握，会引起什么严重后果等。

3.4 课后推销

科学技术的迅猛发展，使我们面对的知识越来越多。而课时、时间、精力都是有限的，我们不可能在有限的时间内把有用的知识都讲完，而且知识是不断的更新、变化的。因此，老师有时可能只能起到“师傅领进门的作用”。学生到底能不能学好，还需要课后推销。课后推销的具体内容可以是：

课程学习了什么知识，还有什么重要的知识因为时间关系没有学到；课程的发展方向，存在的问题，你是否有解决问题的信心；通过课程前面的学习，你掌握了自学的方法么？

4. 在《电气工程基础》课程中的实践

《电气工程基础》课程，是我们学校电气工程及自动化专业大学二年级下半学期开的一门专业基础课，它包括了电力系统一次部分和二次部分，有较多的理论知识和实践经验[3]，对于在校学生来说，想学好不容易。我们上课时，除了遵循一般的教学规律外，还对学生学生进行了课前、课间和课后推销，取得了良好的教学效果。例如，电气工程及自动化专业 08 级学生：

首先在上第一节课时，对学生做课前推销：

《电气工程基础》是电气工程及其自动化专业的一门专业平台课，它应该在学完电路、电子技术、电机学等课程的基础上学习，学完本门课程后，才可以学习后续的《电力系继电保护》、《电力系统分析》、《电网监控及自动化》等课程，在课程设计和毕业设计中，大量用到它的知识，它是一门承前启后的、强电和弱电相结合、非常重要的课程[4]。之所以说它主要，看一下它的内容吧！它共分十章：电力工程概论；电力网及其分析；电力系统的一次设备；电气主接线与配电装置设计；电力系统短路电流计算；电气设备的选择；电力系统继电保护；发电厂和变电所的二次系统和自动装置；接地与电气安全和电力系统过电压保护等[5]。

根据所学的内容，我们就可以知道，本门课程的任务是：如何为用户提供安全、优质、可靠的电能。学完本门课程，学生应该具备电力系统基本的一次和二次设计的能力；电力系统或工厂变电所的运行、维护和管理能力；电力系统问题的解决和创新能力[6]。

若学生学好本门课程，就可以到很多设计部门（例如、电力设计院、建筑设计院，化工设计院，机械设计院等）就业，可以到发电厂和电力系统就业，可以到所有的工厂（工厂都有变电所）就业。总之，只要是用电的地方，都有用武之地，都可以成为电气方面的专家。当然，前提是要学好，要不然，如何能胜任工作！

其次经常在课间对学生进行推销。例如我们在讲电气主接线时，首先要学生了解，衡量电气主接线好坏的标准是：安全、可靠、经济、灵活。那么如何设计才能保证人身和设备的安全？如何设计才能保证供电的可靠？如何设计才能更省钱？如何设计才能运行灵活？要让学生充分体会到它的重要性[7]。

在课程结束时，要做课后推销。因《电气工程基础》课程内容较多，而我们的学时有限。例如电力系统继电保护和自动装置，在课堂上只能做简要的介绍，不能做深入的分析。我们就会告诉学生，现在电力系统的控制和保护的发展趋势是：全部实行遥测、遥控、遥调、遥信的自动化功能，学生要想做这方面的大家，还需要继续学习等[8]。

在考试不画重点及考题不简单的情况下，我们采用了这种教学方法，使学生平均成绩达到 80 分以上。

5. 结论

我们的教育宗旨是：一切为了学生：一切为了学生的成人、成才和持续发展。调动创造性、好奇心；让学生学会学习、自律和充分发挥潜能；激发职业道德和个人责任感。为此，每位教育工作者可能都呕心沥血，终其一生所能。用我的一点感想和实践与大家探讨，希望能有所收获。

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PART II Researches and Developments

第二部分 科研论文