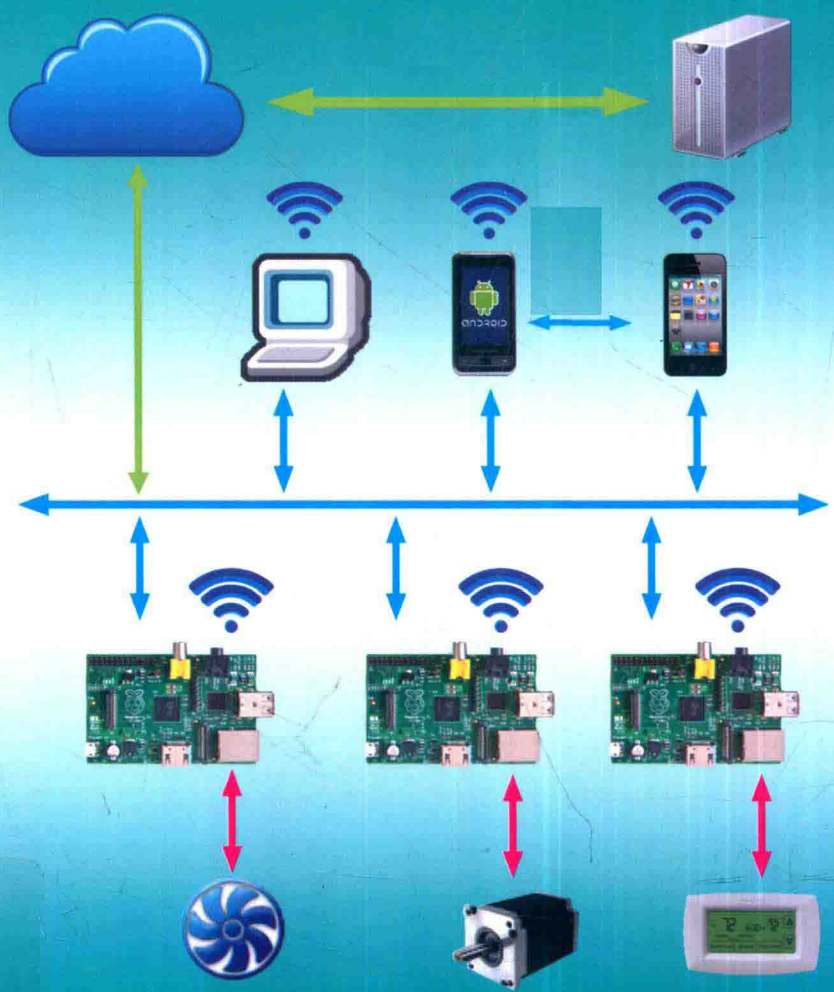
Connectivity and Integrated Approach for IoT

物联网连通性及系统集成

（英汉双语）

Norman Yu（美） 朱怀中 齐从谦 编著



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内 容 提 要

本书是一本针对物联网、智能手机和各种嵌入式设备应用开发的实用性技术书。全书以通俗易懂的语言，尽可能详尽的说明以及大量的开放性源代码，为读者介绍物联网平台的搭建，如何连接各种便携式设备和各类智能装置，以及整个物联网系统集成的方法。书中公布的大量源代码都来自工程实践并经本书作者一一调试，验证了它们的正确性。

全书包括 HTTP API 服务器运行机制、带套接口的内联网通信编程、Web 服务器与 Web 页面、树莓派系统、Linux 内核和应用程序编程接口及携带树莓派的无线网格网等 6 章。全书内容新颖、充实，重点突出，特色鲜明；每章中的代码均具有特定的功能，作者对那些重要的代码行都加注了英、中文注释，以帮助读者更好地理解其作用。

本书可作为高等学校工科类计算机科学与技术、网络工程、通信工程、电子信息技术、汽车电子、电力电子、航空航天等专业的教学用书，也可以作为计算机、通信类职业技术培训教材以及相关行业工程技术人员的参考用书。

图书在版编目（CIP）数据

物联网连通性及系统集成 = Connectivity and Integrated Approach for IoT：英汉对照/（美）余（Yu，N.），朱怀中，齐从谦编著. —北京：中国电力出版社，2016.1

ISBN 978-7-5123-8525-2

Ⅰ.①物… Ⅱ.①诺…②朱…③齐… Ⅲ.①互联网络-应用-英、汉②智能技术-应用-英、汉 Ⅳ.①TP393.4②TP18

中国版本图书馆 CIP 数据核字（2015）第 269943 号

中国电力出版社出版发行

北京市东城区北京站西街 19 号 100005 http://www.cepp.sgcc.com.cn

责任编辑：杨淑玲 责任印制：蔺义舟 责任校对：太兴华

汇鑫印务有限公司印刷·各地新华书店经售

2016 年 1 月第 1 版·第 1 次印刷

787mm×1092mm 1/16·16 印张·384 千字

定价：49.80 元

Preface

The development of modern computer systems and the Internet is depending on human interaction and practice. People can capture Data through various forms of actions such as typing, pressing a record button, taking a digital picture or scanning a barcode. However, human beings have limited attention span, accuracy and time. As a result, we can't capture Data in an ideal and perfect way. How can we address human inadequacy in capturing and storing Data? It will be much more efficient if computer systems are able to keep track of data without human interaction. We only need to replace and repair the computer systems if they become worn out or break down. There is a need for computer systems that are able to capture data and upload information to Internet without the interaction with human. Another term for those systems is Internet of Things (IoT) , which has great potential to change the world, just like what the Internet has done. Maybe IoT's potential is even greater than the Internet with its open sources and a lot of the enabling technology.

In the future, there will be many IoT devices out there and each one would require an IP address. The current IPv4 addressing scheme and space will become inadequate. IPv6 will definitely be used in order to accommodate larger address space and its adoption will be accelerated because of IoT.

Even though it's still at an early stage, the industry is fully aware of the coming IoT and everybody is preparing for it. In the hardware sector, low-cost embedded processors needed for the IoT have been developed, which lays a foundation. CPU used for Smart Phone and Android Wearable devices will strengthen the IoT like the processors. As a recent survey has indicated IoT, embedded technology and wearable computing will have become widespread by around 2025 .

More advanced and useful features will be added to IoT. For example, ambient intelligence or artificial intelligence and autonomous control will be incorporated to enable devices to predict and act in a non-deterministic way. Machine learning algorithm in those devices will be utilized to gather data and interact with other devices, such as intelligent entities (Web services, SOA components) and virtual objects (avatars) in an open network.

There is a vast field of IoT applications, including home automation, environment sensing, smart product management, social interaction gadgets, and smart meters. The list goes on. Basically, the goal is to connect everything in the digital domain and all their gathered data will be uploaded to the servers in the Internet in which an array of computers will be utilized to monitor and analyze autonomously. The intelligent servers can even send the responses back to IoT devices to instruct what will be the next step of the action.

Thus, IoT, or embedded intelligence in things, with "smart systems that are able to take over complex human perceptive and cognitive functions yet overcome human's limitations and act autonomously", is a close reality. It will help make our lives easier in many aspects. And we are in the cusp of such widespread event.

The low-cost embedded CPU and embedded OS will lay a foundation for IoT.

In this book, we have chosen to focus Linux instead of proprietary OS because first it's open source and widely adopted in the development of Android based Smart Phone and wearable devices.

One of the most popular low-cost embedded system is Raspberry-Pi system. There are a lot of developments in this system, so we will focus on this ARM processor (Broadcom) based system. China's Loongson group has developed the MIPS based embedded system for IoT. Although it is behind Raspberry-Pi in its overall development, it has prospect in the future. All of them are running on Linux as a traditional Micro-controller based system without demanding requirement for the software ability to handle IoT.

Since IoT is an overall ecosystem there are a lot of enabling elements in it. It involves embedded system, embedded OS, sensor devices, network, Mobile devices, computer, and the Internet. It includes servers with API backend which can handle the data captured and uploaded to them from IoT devices.

In this book, we will try to integrate the different components in the ecosystem of IoT, including the API/Web server, Mobile systems like iphone and Android are ubiquitous nowadays, and the controller system made of the Raspberry-Pi that controls various sensors in the local network. The mobile system and the Pi communicate with each other through TCP/UDP sockets. Each Pi system can be accessed from outside the local network if a web server exists inside each Pi. This will allow each Pi to independently access any controller in the world. We will elaborate on the important Mesh wireless network using BATMAN, an advanced layer2 routing algorithm included in the latest distribution of Debian Linux OS for the Raspberry Pi. We will also include a real commercial project involving hundreds of Pi. For the sake of cost, (IoT devices need to be low-cost in order to be practical) we can't have dedicated network repeater to cover the large network in a large commercial building.

In the future revision of the book, we will plan to include Machine Learning algorithm which is important in many applications of IoT. Machine Learning enabling systems have certain intelligence and are able to predict the outcome based on previous experiences. It will help the system control things and record data without much human interaction.

As for China, how far it can go in the IoT in the future depends on the low-cost CPUs running on embedded Linux and a wide variety of sensors connecting the system. The sensors include motion sensors, temperature sensors, infrared sensors, humidity sensors, pressure sensors, opto drivers, Wi-Fi adaptors, motor drivers, OPAMP as well as a wide range of analog chips. China is realizing its plan to invest 5 billion dollars yearly to build up its semiconductor industry and is striving to become number 1 in semiconductor output in the world by 2030. IoT also has a promising future in the Chinese market.

Chinese higher education institutions are currently faced with a challenge of educational internationalization. To meet the challenge, it is necessary to compile a textbook that has both Chinese characteristics and compatibility with higher education in developed countries. Therefore, with the support of China Electric Power Press, we compiled this application-based bilingual textbook, based on the author's multi-years' experience of working on Linux system and the IoT.

As a bilingual textbook, the Chinese version and the English version share the figures and numbering codes to avoid redundancy. Meanwhile, instead of word-for-word translation, this book attaches importance to context consistency and semantic accuracy for readers' convenience. The frequently-used vocabularies and basic grammar of science and technology make this bilingual book reader-friendly.

This book has 6 chapters. Chapter One (HTTP API Server)， introduces the operation mechanism of HTTP API Serve, through the opened codes. Chapter Two (Intro-Network Communication Programming with the Socket), focuses on the Socket and its code in Intro- Network Communication Programming. Chapter Three (Web Server and Web page), elaborates on the operation principle and the structure of Web server. Chapter Four (Raspberry Pi System)， introduces the Raspberry Pi as a kind of low-price and portable (wearable) computer based on Linux, including its function and connecting way. Chapter Five (Linux Kernel Internals and API)， gives a brief introduction of basic knowledge about Linux Kernel Internals and API, data structure and the technologies about RCU read copy update. Chapter Six (Wireless Mesh Network with Raspberry-Pi), makes a systematic explanation of the wireless mesh network with Raspberry-Pi and integrated approach of the IoT system.

Mr. Norman Yu, an American software engineer works at Silicon Valley in California, he wrote the English text of this book, and provides the total source codes related to this book. Professor Qi Congqian compiled and edited the preface and Chapter 1,2,6 and Addendum. Doctor Zhu Huaizhong compiled and edited Chapter 4,5. Ms Cuiqian compiled and edited Chapter 3. Mr. Fang Gong, a senior engineer, edited and normalized all the figures finally. Professor Qi Congqian finally, compiled and edited the entire bilingual text of the book.

This book can be used as the bilingual textbook for students majoring in Computer Science & Technology, Network Engineering, Communication Engineering, Electro-Information Technology, Automation, Automotive-Electro Technology, Power Engineering, Power Electronics, Air-Aerospace Engineering. Besides, it can also be used as a reference book in vocational training and for technical and engineering staff in relative industry.

Due to the limitation of our knowledge and profundity of Linux and IoT, mistakes and errors can be found in this book. We are open to valuable advice and comments from all readers for further revision of the book.

Norman Yu, Zhu Huaizhong, Qi Congqian

前　言

现代计算机系统及互联网络的发展取决于人类的交互和实践活动。人们能够通过各种方式，譬如敲击一下键盘、按下一个录制按钮、制作一幅数码图画或扫描一个条形码来获得各种数据。然而人类获取数据的能力似乎还不是那么完美，因为人的视野总是有限的，还缺少足够高的精确度和充足的时间，所以人类从现实世界中获取数据的能力还不甚理想。那么怎样做才能弥补人类这种获取和储存数据的不足之处呢？这一点显得至关重要：如果令计算机系统保持与数据之间的良好联系，而且不必依赖于人与人之间的互动就能有效地获取数据，那将会是一种十分理想的办法。即使计算机系统（因数据量太大）变得乏力无能或者索性宕机，那也只需要对它们进行替换或者修复就可以继续工作下去。因此，使用一种新式的计算机系统，它不依赖于人与人之间的互动，具有自动获取数据的能力并且能把这些数据上传到互联网上，这将会是非常有利和高效的。这种系统的另一个术语叫做“物联网——IoT”，它就像互联网所做到的那样，对改变世界具有极大的潜力。或许，在其开放性源代码及我们所涉及的领域中所带来的大量使能技术方面，物联网将拥有更为巨大的潜力。

将来，会有很多装置和设备连接到物联网上，它们中的每一个都需要有一个 IP 地址。因此当前的 IPv4 所规划的地址空间将被耗尽，从而不能再满足需求。IPv6 肯定要被用来提供足够大的地址空间，它将因物联网的发展而快速地为世人所接受。

尽管物联网行业可能还处于早期阶段，但是该行业似乎已经充分认识到物联网时代的到来，而且几乎每个人都在为此做好准备。在硬件领域，物联网所需要的大量低成本嵌入式处理器已被开发出来，为之打下了基础；用于智能手机的 CPU 和可携带（或可穿戴）的安卓器件也会像处理器那样将使物联网进一步得到壮大。根据最近对大多数技术专家和互联网用户的调查，被调查者中以压倒性的多数表示，物联网、嵌入式技术和便携式计算在 2025 年前后将会得到非常广泛的应用。

更多先进的性能和有用的特征将被注入物联网之中。例如，环境智能或人工智能以及自主控制等这些原本不属于物联网的技术单元，都将被融于其中，从而能进行预测并以非确定方式发挥作用。这些设备中的机器学习算法将在收集数据和与其他设备，例如位于一个开放网络中的智能实体（Web 服务，SOA 组件）、虚拟对象（形象化符号）进行交互方面得到应用。

在一个非常巨大的领域内，包括家庭自动化、环境感知、智能产品管理、社会互动创新及智能仪表等方面，物联网将会大有用武之地。而且应用的范例不胜枚举。从根本上说，其目标就是要把各种各样的数字化信息连接起来，并且把所得到的全部数据上传到互联网的服务器中。在那里有一大批计算机，这些数据将被用于自动化监控和分析并为人类服务。智能服务器还能发送监控和分析结果，把响应返回到物联网设备，以指导下一步的行动。

这样，物联网，或者把它说成是“一种可以替代人类的复杂感知和认知功能，甚至能够克服人类的局限性而进行自主活动的智能系统”的实现即将成为现实。它能够在很多方面帮助人类生活得更为便利和简捷，而我们自己恰恰置身于如此广泛事件的巅峰。

低成本的嵌入式 CPU 和嵌入式操作系统将成为构建物联网的基础。在本书中，我们将以 Raspberry、Linux 系统及基于安卓的智能手机和便携式设备的开发为重点进行介绍，并进一步为物联网的开发打下基础。之所以看好 Linux 而并非所有的操作系统，主要是看中了它的开放式源代码和广泛的适用性。

当前最为流行的低价位嵌入式系统是 Raspberry Pi（一款基于 Linux 系统的个人电脑系统），在该领域内已经开发出一大批产品，我们则重点介绍美国博通公司基于该系统开发的 ARM（Advanced RISC Machines）微处理器；还有可用于物联网的由中国君正集团首创的基于 MIPS 的嵌入式系统——龙芯。尽管它在综合开发方面还滞后于 Raspberry Pi，但考虑到未来的因素，龙芯还是具有相当好的开发前景。所有这些都是作为基于传统的微控制器系统运行在 Linux 之上的，而且它们在从事物联网开发的软件能力方面没有太高的要求。

因为物联网是一个整体的生态系统，所以其自身拥有大量的使能元素，其中包括内嵌操作系统的嵌入式系统、传感器件、网络、移动设备、计算机及互联网。位于 API 后端的服务器不仅能处理所捕获的数据，而且还具有将这些数据上传到物联网设备上的能力。

在本书中，我们尝试把构成物联网整个生态系统的各种不同形式的组件集成起来，其中包括 API/Web 服务，诸如当今到处流行的苹果手机（Iphone）和安卓移动系统以及由 Raspberry-Pi 组成的控制器系统，它们能够控制位于局域网上的各种类型的传感器。移动系统和 Raspberry-Pi 之间可以通过 TCP/UDP 套接口协议进行通信。如果在每个 Pi 的内部设置了 Web 服务器，那么每个 Pi 系统又能被局域网外部的信主访问，这样，每个 Pi 就可以独立地访问位于世界上任何地方的控制器。我们还将讨论在 Raspberry Pi 的最新布局之中使用 BATMAN 工具，这是一种包容于 Debian Linux 操作系统内的、先进的二层路由算法的无线网网格。本书还将涉及一个包含上百个 Pi 的实际商业项目：一个处于大型商业建筑之中的大型网络的每个 Pi 单元都会成为其中的一个网格节点，并具有令路由数据包贯穿整个网络的能力。我们不能采用专用网络中继的方法来覆盖这种大型网络，唯有采用低价位的 Pi 来实现才有意义——因为物联网只有低成本才能更实用。

在将来本书再版的时候，我们计划把机器学习算法作为新的内容，因为这是物联网很多应用的重要内容。机器学习使能系统具有一定的智能以及根据先前的经验来预示后果的功能，它能对系统如何控制物联网中的设备有所帮助，从而不需要人的更多介入就能管控它们并纪录数据。

至于中国，在未来几年内能够在物联网方面走到多远，这不仅取决于运行在嵌入式 Linux 上的低成本 CPU 的价格，而且还依赖于在系统中接入各种类型的传感器，包括运动传感器、温度传感器、红外传感器、湿度传感器、压力传感器等以及光电驱动元件，Wi-Fi 适配器，电动驱动器，各类运算放大器及大量的模拟芯片。就像中国计划到 2030 年，每年投入 50 亿美元的计划来夯实它的半导体行业基础，以成为世界第一的半导体输出大国那样，物联网在中国的实现和发展也将指日可待。

当前，由于国际互联网的迅猛发展及全球的高度信息化，高等教育的国际化已成为国内众多普通高等本科院校的迫切需求；编写具有中国特色，又逐步与发达国家接轨的教材，是中国高等学校教学改革中的一个新课题。为此，在中国电力出版社的支持下，作者在长期从事 Linux 系统的研究和基于 Raspberry Pi 的物联网技术应用开发的基础上，编写了这本英汉双语教材。

由于本书为双语教材，为避免全书篇幅过多，对书中各章内的插图及例程代码采取了中英文页面共享的表达方式，也就是说，同一章节位于英、中文页面内的代码都是做了编号且连续的。在具体内容上也并非是中英文的对等互译，而是强调基本内容的一致性和中英文词义、语义的准确性，从而达到中英文优势互补的效果。英文叙述中尽量采用常用的词汇和简单的科技语法，使读者容易阅读理解，使本书具有更好的可读性。

本书内容共包括 6 章。第 1 章 HTTP API 服务器运行机制，首先介绍了 HTTP API 服务器的工作原理，所公布的源代码具体展示了 HTTP API 的运行机制；第 2 章带套接口的内联网通信编程，重点讨论了内联网通信中的关键内容——套接口的编程实现；第 3 章 Web 服务器与 Web 页面，详尽地描述了 Web 服务器的架构及主要功能；第 4 章树莓派系统，重点介绍了树莓派系统的硬件、基于 Linux 系统的廉价且便携式电脑的基本架构、主要功能及与嵌入式设备的连接方法；第 5 章 Linux 内核和应用程序编程接口，简要地介绍了 Linux 的内核，数据结构、链接清单等基础知识，通过代码展示了遥控设备单元的读取及复制更新的方法等内容，以及第 6 章携带树莓派的无线网格网，系统性地展示了以树莓派为主要连接对象所构建的物联网系统集成的方法。全书内容新颖、充实，重点突出，特色鲜明；每章中的代码均具有特定的功能，作者对那些重要的代码行都加注了英、中文注释，以帮助读者更好地理解其作用。

本书由工作在美国加州硅谷的软件工程师 Norman Yu 先生撰写了英文全文，并无私地公布了与全书内容相关的全部源代码；上海师范大学天华学院朱怀中博士、崔芊老师和齐从谦教授对全书进行了编译和注释（齐从谦负责导言和第 1、2、6 章及附录，朱怀中负责第 4、5 章，崔芊负责第 3 章）。方躬高级工程师对全书插图进行了精心的编辑和规范化处理，全书统稿工作由齐从谦完成。

本书内容新颖，重点突出，特色鲜明，书中具体内容和实例特为高等学校工科类计算机科学与技术、网络工程、通信工程、电子信息技术、汽车电子、电力电子、航空航天等专业的广大学生和教师度身定做。可以作为上述各类专业的教学用书，也可以作为计算机、通信类职业技术培训教材以及相关行业广大工程技术人员的参考用书。

由于编者水平有限，加之 Linux 和物联网本身博大精深，书中难免有错误和疏漏之处，敬请各校师生及广大读者批评指正。

Norman Yu、朱怀中、齐从谦

于上海嘉定天华园

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Chapter 1 HTTP API Server

In the IoT scheme of things, server with centralized database that devices being able to access for uploading data or reading data is one of the basic building block. People are more familiar with the term Web Server which serves HTML Web pages to the Client Machine but what's an API Server? API (Application Program Interface) is a set of software routines and it operates over HTTP (HyperText Transfer Protocol). HTTP API Server provides a mechanism of reading and updating the centralized SQL database. HTTP is the standard protocol being used in internet today. Every time you open a Web page, it generates a request to the Web Server across the internet using HTTP Protocol.

Fig. 1-1 shows how a normal Web Server looks like. It serves HTML Web pages across the Web. It has it's own database. However, the limitation to this is what happen when there are other devices out there that need to access the SQL database information and they don't have Web browser to view the contents served by the Web Server.

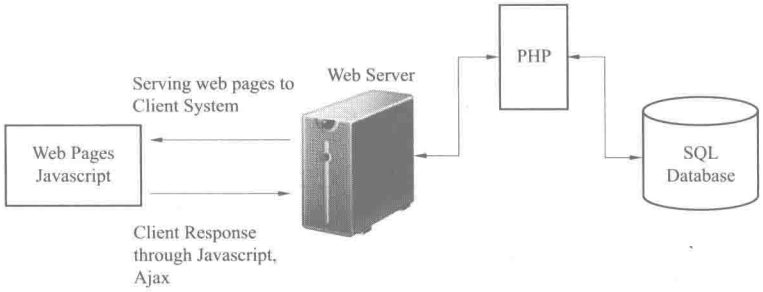

Fig. 1-1 A Web Server serving Web pages with its own SQL database

图 1-1 自带 SQL 数据库的 Web 服务器网页

So, we need to have a more generic way to able to provide centralized SQL database information to everything out there in the internet. We need to break up and take out the SQL database and that's where API Server comes in. It provides a simpler output and input of information; instead of fancy of serving Web pages of all kinds of content (pictures, music, multimedia). API Server using only generates text based output in either XML or JSON format. JSON is the simpler of the two and it is a light weight data exchange format and widely used today. In this book, the API Server output is based JSON. It's a two fields format which includes key and value pairs.

This JSON syntax defines a people object, with an array of 3 person records (objects):

第 1 章　HTTP API 服务器运行机制

在物联网中，对拥有集中式数据库的服务器及各种控制对象等设备的规划都是设法令其具有上传数据或读取数据的能力，而使之成为物联网的基本构件之一。Web 服务器就是人们耳熟能详的一个项目，它把 HTML 格式的 Web 网页提供给客户机。那么我们应该怎样理解这种 API 服务器呢？API（应用程序界面的英文缩写）是一套软件例程，它能够工作在 HTTP（超文本传输协议的英文缩写）协议之上。HTTP API 服务器提供了一种对像 SQL 那样的集中式数据库阅读和更新的机制。HTTP 就是当今被用于互联网中的一个标准协议。无论在哪一时刻，你只要打开 Web 网页，它就会使用 HTTP 协议并通过互联网向 Web 服务器发出一个请求。

从图 1-1 可以看出一个正常的 Web 服务器是如何工作的。它有一个属于自己的数据库，可以通过 Web 发出一个 HTML 格式的 Web 网页。然而，在这种情况下，恰恰会产生某种局限性：当此刻有其他的设备也需要访问 SQL 数据库的信息时，它们就缺少 Web 浏览器，无法浏览由 Web 服务器发来的内容。

这样，我们需要有一个方法，那就是不管在互联网上发生何种事情，Web 服务器都可以提供一个以 SQL 数据库信息为中心的功能。为此我们需要申请中断并去取出 SQL 数据库中的信息，也就是说，进入 API 服务的工作界面。该界面能提供一个更为简洁的信息输出和输入方式，而且能提供出包括所有类型的 Web 网页，其中包括图片、音乐甚至多媒体等，这其实并非是幻想。API 服务器仅仅使用基于文本形式的内容就能输出 XML 和 JSON 中的任一种格式。JSON 则是这两种格式中更简洁的格式，而且它还是一种轻量级的数据转换格式，在当前的互联网上得到广泛的应用。在本书中，所介绍的 API 服务器的输出就是基于 JSON 的格式。它是一种包含一对密钥和值的两字段格式。

下列代码是以阵列方式定义一个对象的 JSON 语法形式，它给出三个人姓名的记录。

我们在图 1-2 中所看到的和图 1-1 的情况正好相反，Web 服务器的数据库信息被取出而且马上储存到 API 服务器中，下一步供客户机浏览也就不成问题了。Web 服务器和 API 服务器

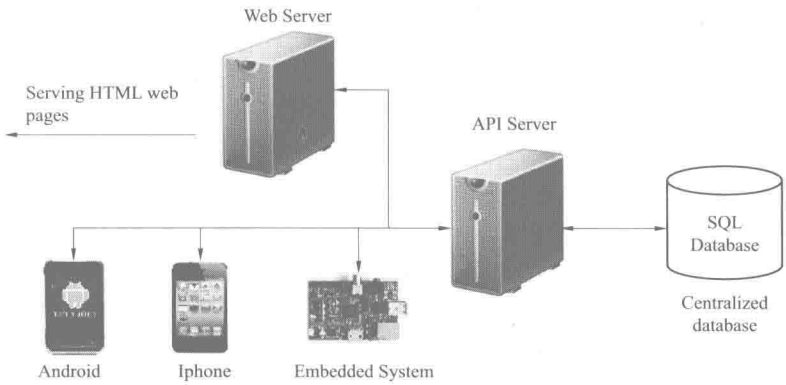

Fig.1-2　An API Server serving multiple devices across the Web using simple data exchange format such as JSON

图 1-2　使用简单数据转换为 JSON 格式的服务器为多种设备提供跨网页服务

```
{"people": [ {"firstName":"John", "lastName":"Doe"},
             {"firstName":"Tom", "lastName":"Lee"},
             {"firstName":"Nancy", "lastName":"Jones"} ]
}
```

In Fig.1-2, it shows that in contrast with Fig.1-1, the database of the Web Server is taken out and now everything is stored in the API Server system. The Web Server and API Server do not have share the same system or physically they can be in different locations. So for conceptual purpose, the diagram is shown the two servers are using two different systems. However they can be reside in the same computer system but need to setup HTTP access rules so they can be accessed differently.

1.1 Inside Look of an API Server

We have setup an API Server and a Web Server in the same machine using a commercial Web hosting service company named GoDaddy. The key to control accessing which server is through a file .htaccess. It's a directory level configuration file that conFig.s the server. It's places at root level of directory. It's used to restrict access to files per-directory basis. It's similar to Apache server's httpd.conf file.

1.1.1 About .htaccess file

In Fig. 1-3, top level folder, and notice the .htacess file and the api folder. The .htaccess file controls the access of the files and routing of the request. The api folder contains the REST api request call handler.

The followings are codes of .htaccess file in which "RewriteRule ^api/(.*)? api/api.php [QSA,L]" means: "my domain is http://www.metrizolution.com and if a user make a API call like http://www.metrixzolution.com/api/session/login it would be routed to the api folder and handled by the api.php file". "RewriteRule ^api/(.*)? api/api.php [QSA,L]" means: "I have setup two API Server. The first one is handled by the api.php inside the api folder and the second one is handled by the second_api.php. They have different SQL tables and their data are separate, http://www.metrizzolution.com/second_api/session/login would be handled second_api. php."

.htaccess file

```
01  # Don't show directory listings for URLs which map to a directory.
02  Options -Indexes
03  RewriteEngine On
04  RewriteCond %{REQUEST_URI} !play2win_api\.php
05  RewriteRule ^api/(.*)?     api/api.php [QSA,L]
06  RewriteRule ^api/(.*)?     api/api.php [QSA,L]
07  RewriteCond %{REQUEST_FILENAME} !-f
08  RewriteCond %{REQUEST_FILENAME} !-d
09  RewriteRule ^ index.php [L]
```

没有共享同一系统，或者说它们实际上可能位于不同的物理位置。这样，从概念意义上来说，就像图形界面所展示的那样，两个服务器用在两个不同的系统。然而，它们却可以跨接在同一个计算机系统之上，但是必须启用 HTTP 协议的访问规则，以确保它们能实现各自不同的访问。

1.1 从内部窥探 API 服务器

我们可以在同一台计算机上用一个名为 GoDaddy 商业服务公司的 Web 网站启动一个 API 服务器和一个 Web 服务器。控制访问的关键是通过一个扩展名为.htaccess 的文件实现的。它是一个为服务器配置工作路径的配置文件，通常置于根目录层上。它被用来控制对每个目录基础访问的权限，与 Apache 服务器中的 httpd.conf 文件的功能十分相似。

1.1.1 关于 .htaccess 文件

从图 1-3 和图 1-4 可以看出：顶层的目录显示出 api 文件夹以及.htacess 文件。.htacess 文件控制对文件的访问并指向请求路径。而 api 文件夹则包含调用 api 处理程序的请求 REST。

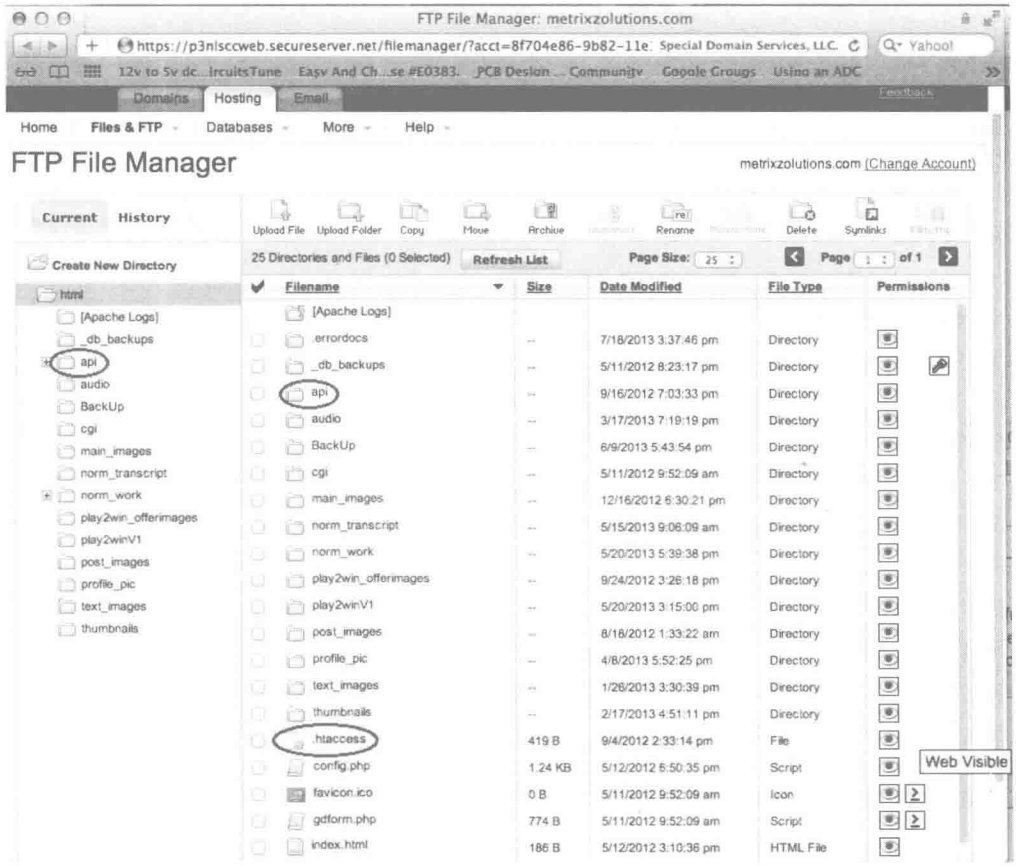

Fig. 1-3 API Directory and .htaccess File in the FTP File Manager

图 1-3 文件传输协议文件管理器中的 API 目录及.htaccess 文件所在的位置